Business Case for Arviat Wastewater

Final Report Rev 01

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BUSINESS CASE FOR ARVIAT WASTEWATER

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Executive Summary

The Arviat Wastewater Business Case study is a comprehensive study on the wastewater treatment facility (WWTF) expansion options evaluation and selection to meet the needs of the Hamlet of Arviat's (the Hamlet) wastewater treatment and disposal needs. This Business Case study projected the flow and loadings based on the population growth, proposed the treated effluent goals and standards, reviewed and selected the most suitable location and treatment technologies, conducted a conceptual level geotechnical investigation and environment assessment, sized the lagoon system and conducted a conceptual schematic design. The six passive lagoon treatment systems were compared for merits and disadvantages in the content of the Arviat location conditions. The Business Case study recommended the most suitable options for the wastewater treatment and disposal in the Hamlet.

Previous study on the Arviat's wastewater treatment lagoon-wetland system documents were reviewed to allow a better understanding of the current wastewater collection practice, and configuration, condition, and performance of the existing wastewater treatment facility (WWTF). Regulations pertinent to the construction and operation of a Wastewater Treatment Facility (WWTF) on municipal lands within the Hamlet were identified and reviewed. In addition, treatment goals for the lagoon-wetland effluent criteria were established as 100, 120, and 1.25 mg/L for carbonaceous biochemical oxygen demand (cBOD), total suspended solids (TSS), and un-ionized ammonia as nitrogen (NH_3-N), respectively.

Given an estimated population of 2,657 residents in 2016 (Statistics Canada 2016), the design population to be serviced by the WWTF was projected to be 4,338 people in 2040. This population will contribute a design flow rate of 434 m^3/d at the end of the design horizon, requiring active storage volumes of 130,200 m^3 and 158,410 m^3 for 10 and 12 months of storage, respectively. Raw wastewater quality was suggested based on the National Standard of Canada "*Planning, design, operation, and maintenance of wastewater treatment in northern communities using lagoon and wetland systems*" (CSA W203:19).

To determine the most suitable technology for the new WWTF, several lagoon and mechanical plant alternatives were evaluated. It was recommended that the most common technology for wastewater treatment in a remote and rural communities in the Arctic is wastewater lagoons for their relatively low capital cost, simple operation, and acceptable treatment results. It was agreed upon by both Nunami Stantec and the Hamlet that this project is to proceed forward with a lagoon system as the treatment technology in its wastewater treatment and disposal.

A high-level geotechnical investigation study and an environmental assessment screening study were carried out to determine the suitable locations for the wastewater treatment facility. Based on the review of terrain and geotechnical conditions, environmental and planning impacts assessment, and community and government consultation, 13 sites within the Hamlet were identified and evaluation through a location selection matrix. The preferred locations for lagoon expansion are the current site (Site 1) and Site 13.

Multiple conceptual lagoon system layout and configuration options were developed to meet the Hamlet's wastewater treatment and disposal needs. Schematic design and operation strategies have been defined

in this Business Case report for the major components of the project. Six schematic design options were evaluated as summarized in the following table:

Site	Option Number	Total System Storage (months)	Existing Wetland	Description
Site 1	Option 1	10	Available	New cell addition to the east and the existing lagoon
	Option 2	10	Available	New cell addition to the east and retrofitted existing lagoon
	Option 3	12	Available	New cell addition to the east and new cell over demolished existing cell
	Option 4	12	Available	New cell addition to the east
	Option 5	10 with provision for additional 2	Available	New cell addition to the north and the existing lagoon
Site 13	Option 6	10 with provision for additional 2	Not available	New lagoon. Hamlet does not prefer this site, however, have agreed to allow investigation as an alternative site.

Based on evaluation of the six options against a set of criteria, Stantec recommended Option 3 to be implemented at the same site of the existing lagoon (Site 1). In this option, the existing lagoon will be demolished and be replaced with a new cell with an effective storage capacity of 5 months (67,000 m^3). A new cell will be constructed to the east to provide an additional effective storage capacity of 7 months (95,000 m^3), bringing the total effective storage capacity to approximate 12 months. The construction cost of this option was estimated to be [redacted]

In order to complete the design of the recommended option, a few technical studies are to be completed, including a Wetland Study, Detailed Geotechnical Study for Lagoon Design, and Detailed Survey and Assessment of the Existing Lagoon.

1.0 INTRODUCTION

1.1 CONTEXT

Arviat (which means "place of the bowhead whale" in Inuktitut) is located on the western shore of Hudson Bay (61º06'N and 94º03'W) in the Kivalliq Region of Nunavut. The Hamlet has an estimated population of 2,772 (2016 census, Government of Nunavut). Similar to all Nunavut communities, Arviat is only accessible by air and for a limited season by boat.

The Hamlet of Arviat provides wastewater treatment and disposal services for the community under Nunavut Water Board (NWB) License 3AM-ARV1015. Arviat is now serviced by a trucking system for both water delivery and sewage collection. The trucked wastewater is discharged into a 43,000 m^3 (estimated volume) passive, facultative lagoon system located approximately 2.8 km south-west from the Hamlet of Arviat (Figure 1-1). Its effluent travels through a 7.3 ha natural wetland about 440 m west to the Hudson Bay and ultimately flows into the Hudson Bay.

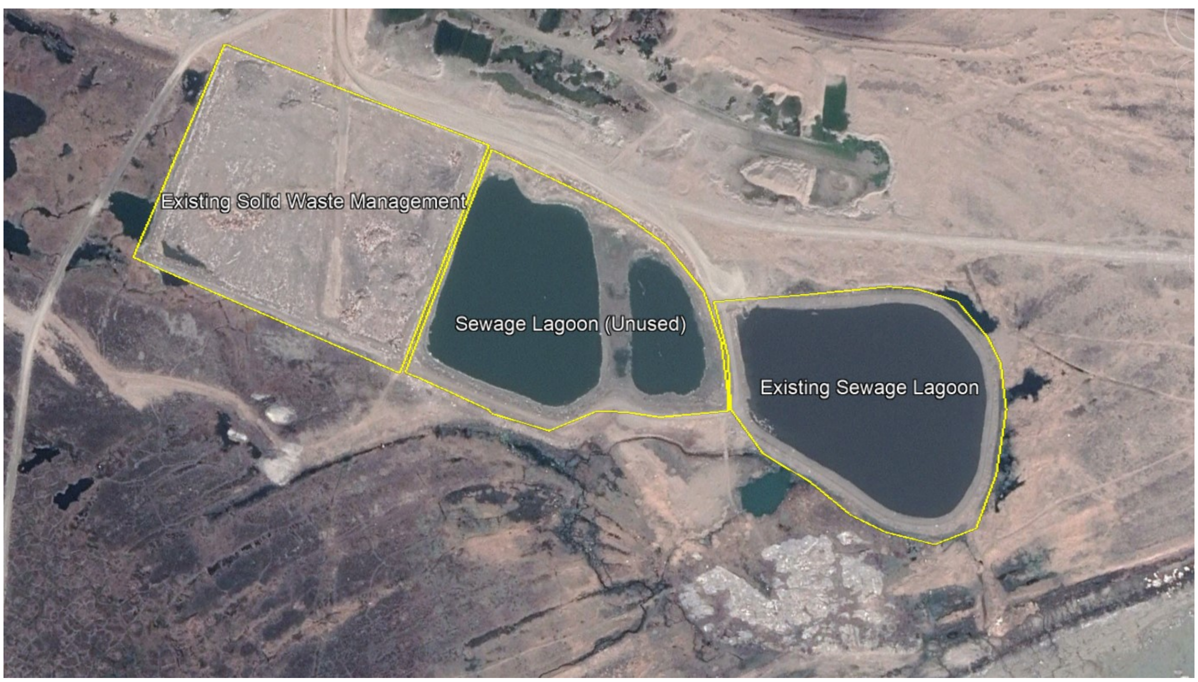

Figure 1-1: Existing Wastewater Treatment Facilities – Lagoon and Wetland

Nunami Stantec Limited (Nunami Stantec) was contracted by the Government of Nunavut (GN) – Department of Community and Government Services (CGS) to complete a Business Case for the Hamlet of Arviat (Hamlet) to study future scenarios for its sewage disposal facility. As the existing lagoon is overcapacity, there have been two possible scenarios identified to deal with anticipated increased volumes of wastewater:

1. **Passive WWTF**

   A new WWTF would consist of multi-cell lagoon system with an impermeable design and controlled discharge to the environment (i.e., wetland treatment area).

2. **Mechanical WWTF**

   This system would require a "holding cell", or Equalization (EQ) tank, to receive trucked wastewater, and a mechanical treatment plant to provide filtration, screening, biological treatment, disinfection, and discharge of treated wastewater to the environment, along with processing and disposal of solids by-product.

During consultation with the GN and the Hamlet, it was determined that the annual costs, operation requirement, and overall complexity of a mechanical WWTF would limit the feasibility of this approach. Though mechanical options are described within this document, the focus of recommendation will be around the passive WWTF, or lagoon options.

2.2 OBJECTIVES AND SCOPE OF WORK

The main objectives of this project are to determine the required wastewater treatment capacity and to provide the process options and to compare their merits and disadvantages in the content of the Arviat location conditions and to recommend the most suitable options for the wastewater treatment and disposal in the Hamlet. A schematic design is also included in the scope as required by the GN.

This planning study presents the following:

- Hamlet population growth and wastewater flow and loading projections;
- Regulatory and discharge criteria research and projection;
- Existing lagoon and wetland capacity review;
- Wastewater treatment and disposal upgrade technologies and options identification including lagoon upgrade and mechanical treatment plant processes and associated odor control technologies;
- Technologies and options comparison and recommendations;
- Schematic/conceptual design development;
- Class D cost estimate for passive WWTF (lagoon) options; and
- Overall recommendation of the lagoon option.

2.0 PROJECT BACKGROUND

2.1 BACKGROUND DATA REVIEW

Several documents are available for review and allow a better understanding of the wastewater management in the Hamlet. Pertinent documents provided by GN-CGS and reviewed as part of the project include the following:

- Sewage Disposal Facility Report - Hamlet of Arviat, Nuna Burnside, 2010
- Hamlet of Arviat Community Plan, https://cgs-pals.ca/
- Arviat Water License, 3AM-ARV1015, Nunavut Water Board Public Registry
- Municipal Wastewater Standards Report

2.2 EXISTING FACILITY REVIEW

2.2.1 Current Wastewater Collection Practice

Arviat is serviced by a trucked system for both water delivery and sewage collection. Sewage is collected from holding tanks either located below or alongside houses and other occupied buildings, then trucked to the wastewater disposal facility, which consists of a lagoon and wetland treatment area. The current wastewater disposal facility is located approximately 2 km south/southeast from the Hamlet, less than 300 m from the ocean (Figure 2-1).

2.2.2 Existing Configuration and Conditions

The existing wastewater disposal facility consists of a single cell lagoon and a post-lagoon wetland. The Hamlet of Arviat Sewage Disposal Facility Report (Nuna Burnside, 2010) which will be referred to as Sewage Report 2010 hereafter, indicates that the existing single cell lagoon in operation was constructed and commissioned in 2005. The lagoon cell was constructed with elevated gravel and sand berms surrounding the 2.3 ha of water storage area. Since accurate as-built drawings were not available to perform detailed calculations, a high-level estimation of the total water volume came up with 43,000 m^3 in the Sewage Report 2010 and the record drawings appended within that report.

The lagoon's southwest berm was designed to have higher permeability to allow the exfiltration of the effluent in the lagoon at a slow and continuous rate. An operator from the Hamlet indicated that the lowest water level observed was 2 meters below the top of the berm during summer as the water moves through the southwest berm. Note that the 43,000 m^3 volume was estimated without detailed as-built drawings. Whether the full depth of the south was constructed with permeable material is unknown. In the detailed design stage, it is recommended to do a full topographic survey and a geotechnical investigation should be carried out to test the berms' permeability.

In spring, the Hamlet is often required to perform an emergency decant prior to spring thaw. This is an indicator that the existing lagoon does not have adequate capacity to handle the wastewater amounts generated from the Hamlet.

The surface-flow style wetland at the southwest side of the lagoon receives the lagoon's effluent. The wetland treats the lagoon's effluent by distributing it over an area of sufficient footprint to allow natural processes to occur before the effluent goes to the Hudson Bay. Natural processes may include sedimentation, adsorption by soil particles, uptake, and digestion of nutrient components by vegetation, microbial decomposition, physical entrainment in changing flow regimes, and dilution by intermixing with the natural water. The total area of the wetland is approximately 7.3 ha as reported in the Sewage Report 2010.

Figure 2-1: Aerial photograph of the Hamlet of Arviat and its existing wastewater lagoon and wetland

2.2.3 Existing Lagoon-Wetland Performance Review

To better understand and foresee the quantitative range of effluent quality, two parameters of the effluent water quality (i.e., total suspended solids [TSS] and carbonaceous biochemical oxygen demand [cBOD]) at the monitoring station ARV-4 is shown in Figure 2-2 and

Figure 2-3 at multiple sampling events during the period from June 2014 to December 2019. The figures also present the effluent limits of 100 and 80 mg/L for TSS and cBOD, respectively, as defined in the Water Licence No. 3AM-AER1015. Note that ammonia is not in the sample test list under the water license.

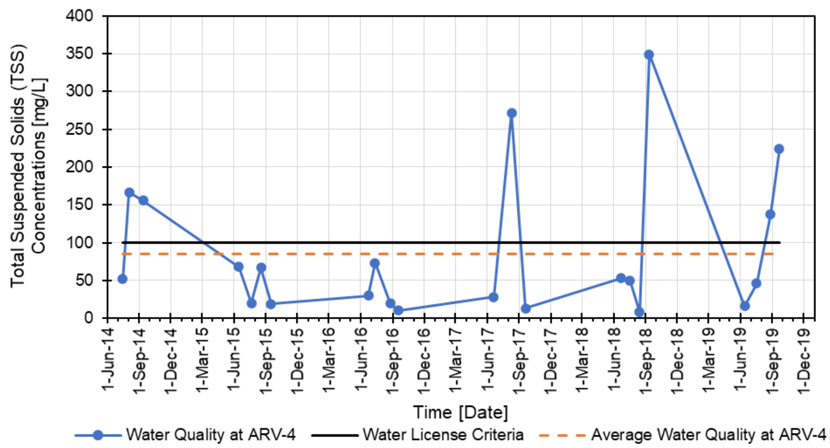

Figure 2-2: Total Suspended Solids (TSS) of the Existing Lagoon's Effluent at the Monitoring Station ARV-4

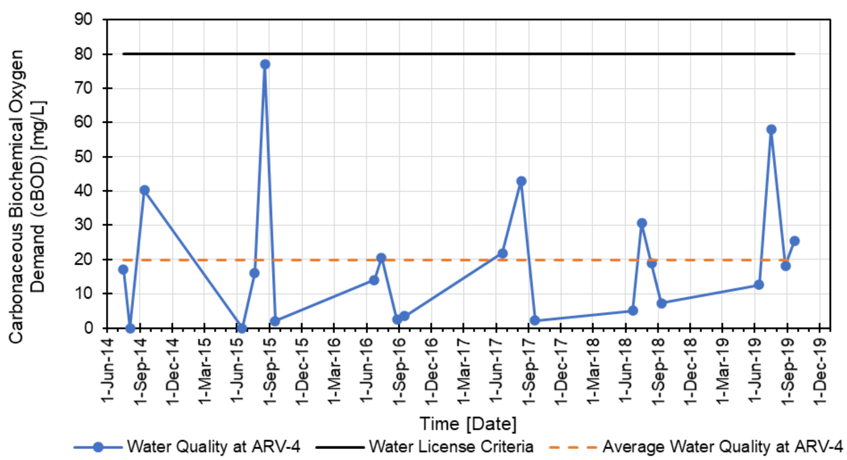

Figure 2-3: Carbonaceous Biochemical Oxygen Demand (cBOD) of the Existing Lagoon's Effluent at the Monitoring Station ARV-4

The figures show that the effluent water quality fluctuates noticeably with average TSS and cBOD of 85.4 and 21.8 mg/L, respectively. Although these average values are below the effluent limits of 100 and 80 mg/L, multiple effluent samples exceeded the effluent limits, not complying to the current water license. The noncompliant results indicated that the lagoon cell might have been overloaded or the samples taken are not representative and from well mixed locations.

Using a design wastewater generation rate of 100 Lpcd (referring to Section 4.1.2) and an approximate population of 3,000 m^3 in 2020, the wastewater generated in the Hamlet is 300 m^3 per day. Given that the effective volume of the existing lagoon is 43,000 m^3, the hydraulic retention time is about 143 days (less than 5 months). This rough calculation result verifies that the existing cell does not have sufficient volume to store the water for the wintertime (10 months). The operator has to pump water out of the cell in springtime to avoid overflow. As indicated in the National Standard of Canada "*Planning, design, operation, and maintenance of wastewater treatment in northern communities using lagoon and wetland systems*" (referred to as CSA W203:19 hereafter) published by the Canadian Standards Association (CSA Group) in 2019, a lagoon in northern region should be able to hold the wastewater for 10 to 12 months during the long winter months. The existing cell storage volume is less than the required volume.

2.3 REGULATORY CONSIDERATIONS

The Hamlet of Arviat is currently holding a municipal undertaking water licence (No. 3AM-ARV1016) issued by the NWB for use of water and deposit of waste. The licence sets the effluent water quality at the Monitoring Program Station ARV-4 (the compliance point; referred to as ARV-4 hereafter) of the Arviat Sewage Disposal Facility, which is located within the wetland, downstream of the lagoon. According to the licence, the water quality at ARV-4 shall not exceed the effluent quality limits shown in Table 2-1.

Table 2-1: Existing Arviat Sewage Disposal Facility Effluent Quality Limits

Parameter	Maximum Concentration of Grab Sample
Fecal Coliform	1 X 10^4 CFU/dL
cBOD	80 mg/L
Total Suspended Solids	100 mg/L
Oil and Grease	No visible sheen
pH	Between 6 and 9

Note: Values are based on CSA W203:19, Table D.1 for single cell lagoon and less than 2.5 m water depth. Ammonia is not required by CSA W203:19 for Nunavut.

Wastewater treatment lagoons or wastewater stabilization ponds are popular in rural communities due to its minimum operation requirement and minimum level of construction scope. If they are designed and constructed properly and operation within their design capacity, lagoons can treat the wastewater to meet primary or secondary treatment standards. In the province of Alberta, the configuration of the conventional wastewater lagoon system, a.k.a. facultative lagoon system, should consist of anaerobic, facultative and storage cells. The design of the cells is regulated in the Alberta Environment and Parks (AEP) design guideline; the water depths and retention time are defined in the guideline. The AEP Standards establishes the desired retention time for each of the cells to achieve the treatment requirements. Once the retention time is met, the treated wastewater is discharged from the storage cell after at least 365 days holding time.

As indicated in CSA W203:19, the conventional lagoon in Northern Alberta can achieve secondary treatment goals (cBOD <25 mg/L, TSS<50 mg/L, total ammonia nitrogen (TAN) <10 mg/L). The operation and monitoring the of the conventional lagoon system are governed by the "*Code of Practice for Wastewater Systems Using a Wastewater Lagoon*". Regardless the confidence on the treatment goals, AEP does not specify 'hard' effluent quality standards for the conventional wastewater lagoons but requires the grab sample testing and reporting, and discharge notification as specified in the code of practice. The reason behind no specifying effluent quality standards is that the taking representative sample from a lagoon cell is very challenging as the lagoon cells are large open water bodies without mixing equipment. A cluster of pollutant, for example, a small amount of re-suspended sludge or a small algae colony can skew the readings. Hence, instead of setting hard limits and use them to determine if a sampling result is out of compliance, AEP put more efforts on the design review and operation inspection. It is suggested that NWB follow the same principal in regulating the passive lagoon system design and operation.

The GN has the authority to recommend and seek the NWB's approval on adjusting the effluent treatment goals based on research conducted by the Centre for Water Resources Studies (referred to as Water Studies) at Dalhousie University. The Water Studies was established to conduct applied research and provide technical support to many government agencies, municipalities, and private sector end-users in the water sector to address water issues facing Atlantic Canada. The Water Studies included a sampling program and Wastewater Stabilization Pond (WSP) or lagoon systems analysis. The key finding from the studies are:

1. The typical NWB standards of 120 mg/L for cBOD, 180 mg/L for TSS and $1X10^6$ CFU/100mL for Fecal coliform can be generally met but not consistently.
2. The 1.25 mg/L unionized NH3-N which is set for the WSP system south of 54^{th} parallel in Wastewater System Effluent Regulation (WESR) can generally be met but not consistently.
3. Algae growth played an important role in the WSP treatment process. Excessive algae can elevate the TSS readings and unionized NH_3-N readings.
4. Water temperature, water depth, sludge amount and operation are also critical factors to the effluent quality.

Yates *et. al* conducted a study on the post lagoon wetland treatment performance on six lagoon and wetland systems, including the system in Arviat, in 2010. The average water quality test results from the weekly samples collected from the wetland effluent showed that the treatment wetland can reduce 47-94% cBOD, TSS 39-98%, 84-99% NH3-N. The treated effluent in the post lagoon wetland has the similar quality to the water quality natural wetland. The performance demonstrates that tundra wetlands after wastewater lagoons are an appropriate technology for remote Canadian Artic communities. However, the effluent concentrations have wide ranges, for example, the cBOD ranges from 0 to 174 mg/L, TSS ranges from 0 to 126 mg/L and NH_3-N ranges from 0 – 40 mg/L. These wide range also imply that using test results from a grab sample to determine if the performance of the lagoon and wetland meet a curtain standard is not practical.

Thus, the GN requested the NWB that the effluent water quality treatment goals outlined in Table 2-1 are to be slightly relaxed, especially further treatment occurs in the wetland downstream of the ARV-4 before final discharge into the Hudson Bay. Table 2-2 shows the GN's proposed treatment goals in the treated effluent at ARV-4.

Table 2-2: Proposed Treatment Goals Measured at ARV-4

Parameter	Maximum Concentration of Grab Sample
cBOD	100 mg/L
Total Suspended Solids (TSS)	120 mg/L
Un-ionized ammonia as nitrogen (NH_3-N)	1.25 mg/L

Note that the cBOD and TSS are actually higher than the CSA W203:19 expected effluent quality from a single-stage lagoon system.

The current location of the ARV-4 is not at the end of the wetland. From a treatment perspective, the samples taken from the current ARV-4 location do not represent the final treatment results of the existing lagoon-wetland system. The Hamlet should relocate the ARV-4 to the end of the wetland flow path, close to the ocean.

2.4 EFFLUENT CRITERIA REQUIREMENTS

2.4.1 Lagoon

Based on the relevant regulatory review and considerations discussed in the previous section, it is not recommended to set the lagoon discharge effluent limits based on random grab sample at the monitoring point ARV-4 during the open water season. Instead, a set of treatment goal at the relocated monitor point ARV-4 are presented in Table 2-3.

Table 2-3: Proposed Lagoon Effluent Quality Goals

Parameter	Maximum Concentration of Grab Sample
cBOD	100 mg/L
Total Suspended Solids	120 mg/L
Un-ionized ammonia as nitrogen (NH_3-N)	1.25 mg/L

The operators should take the samples and have then tested during the effluent discharge season. It is understood that due to logistic difficulties, the hamlet used to take samples in the discharge season for testing (approximately 3 – 4 samples per discharge season). The Hamlet should report the test results to NWB. Note that when the results exceeding the proposed lagoon effluent quality goals should not be treated as out of compliance incident. Rather, the Hamlet and NWB can utilize the test results from multiple discharge seasons to determine the performance trends.

2.4.2 Mechanical Plant

Technology-based discharge limits apply to mechanical plants. Discharge limits based on the monthly average of the daily sample test results are presented in Table 2-4.

Table 2-4: Proposed Mechanical Plant Effluent Quality Limits

Parameter	Maximum Concentration of Grab Sample
Fecal Coliform	400 CFU/ 100 mL
cBOD	25 mg/L
Total Suspended Solids	25 mg/L
Ammonia (un-ionized at 15°C)	1.25 mg/L
pH	Between 6 and 9

Compared to the lagoon discharge standards, the mechanical treatment effluent quality is more stringent. However, much more energy input, chemical, operation labor is needed to operate the mechanical treatment plant. The daily sampling and testing program in operating a mechanical plant is also a heavy burden to this remotely located hamlet.

3. REGULATORY FRAMEWORK REVIEW

Federal and Nunavut territorial acts, regulations, guidelines, and policies pertaining to environmental protection, waste reduction and resource recovery, public health and safety, land and water use, and terms and conditions for leased land exist and will be described in this section.

3.1 REGULATORY APPROVALS

The following legislation and regulations may be applicable to the construction and operation of new waste management facilities, including a Wastewater Treatment Facility (WWTF) on municipal lands within the Hamlet of Arviat:

- Nunavut Agreement
- Nunavut Planning and Project Assessment Act
- Nunavut Waters and Nunavut Surface Rights Tribunal Act and Nunavut Waters Regulations
- Wildlife Act
- Fisheries Act
- Environmental Protection Act
- Aeronautics Act and Arviat Airport Zoning Regulations
- Canada Water Act
- Nunavut Archaeological and Palaeontological Sites Regulations
- Public Health Act
- Arviat Zoning Bylaw and Community Plan Bylaw

Arviat's waste facilities are authorized under type "A" water licence 3AM-ARV1016, which expired in 2015. Based on the location of the studied waste facilities of this report, the construction and operation of new waste facilities is not considered a modification of any existing facility and will therefore require authorizations or approvals from several regulators, dependent on the final design and location. A summary of the potential approvals required shown in Table 3-1.

Table 3-1 Approvals Potentially Required to Construct and Operate New Waste Facilities

Legislation	Authority	Activity	Authorization / Action
Nunavut Waters Regulations	Nunavut Water Board	New waste discharge to environment	Amendment to water licence
Arviat Airport Zoning Regulations SOR /90-793	Transport Canada	Erection of a building, structure, or object within 4,000 m of the specified reference point that exceeds specified elevations	Exemption to Airport Zoning Regulations
Aeronautics Act	NAV Canada	Land use near airport	Land Use No Objection Letter
-	Government of Nunavut - Economic Development and Transportation (GN-EDT)	Any activity that might interfere with airport operations	Letter of No Objection from GN-EDT
Nunavut Planning and Project Assessment Act	Nunavut Planning Commission (NPC)	New project within Nunavut	Determination that no land use plan is in effect; determination whether screening by NIRB is required.
Nunavut Planning and Project Assessment Act	Nunavut Impact Review Board (NIRB)	Project proposal subject to screening	Screening determination (requires approval from Minister)
Fisheries Act	Fisheries and Oceans Canada	Potential for harmful alteration, degradation or destruction of fish or fish habitat	Letter of Advice
Arviat Zoning Bylaw	Hamlet of Arviat	New land use within designated zones	Amendment to zoning bylaw
Nunavut Agreement	Crown Indigenous Relations and Northern Affairs Canada (not confirmed)	Land use within 100 feet of ordinary high-water mark (if applicable)	Notification of use of 100 ft strip for sole benefit of the municipality
Nunavut Archaeological and Palaeontological Sites Regulations	Nunavut Culture and Heritage	Documentation of an archaeological site in the field; no disturbance	Class 1 permit
Nunavut Archaeological and Palaeontological Sites Regulations	Nunavut Culture and Heritage	Documentation and/or disturbance of artifacts	Class 2 permit

The final list of approvals required to construct and operate new waste facilities are determined once final location and preliminary design details are available.

3.1.1 NPC and NIRB Screening Process and Required Information

Once a final site selection is approved and preliminary design is available, the process to obtain regulatory approvals can begin. All new developments (project proposals) must first undergo evaluation steps identified in the Nunavut Agreement and Nunavut Planning and Project Assessment Act (NUPPAA) before applying for specific authorizations to construct and operate. There are three steps to initiating the regulatory process under the NUPPAA:

1. The Nunavut Planning Commission (NPC) determines whether the project proposed conforms to an approved land use plan, and determines whether the project proposal requires screening by the Nunavut Impact Review Board (NIRB);
2. The NIRB conducts a public screening process, and recommends whether the project proposal can proceed, whether it requires a more thorough review, or whether it needs to be reconsidered or abandoned; and
3. The Minister of Crown – Indigenous Relations and Northern Affairs Canada (CIRNAC) accepts or rejects the NIRB's screening recommendation.

To initiate the screening process, the NPC receives a project proposal – a technical and non-technical summary of the project being proposed, identification of authorizations being sought and evidence of engagement with potentially affected communities (called "prescribed information"). As there is no approved land use plan in the region, there is no requirement to demonstrate adherence to an approved land use plan. The NPC will, within 7 days, determine whether the application is complete. It then has up to 45 days to issue a determination of conformity with a land use plan, and of whether screening by NIRB is required. The new waste facilities are expected to require screening by NIRB, as they are not otherwise exempt from screening per Article 12-1 of the Nunavut Agreement.

To commence the screening, the NIRB will open a file and request the proponent to provide additional information required for screening. The key outcome being sought of the screening is whether the project proposal could be a cause of significant environmental impacts or significant public concern. The NIRB can recommend that the project proposal be rejected, approved as proposed, approved with additional measures, or referred to a higher level of review (full review by NIRB).

The information required by the NIRB for screening includes:

- Description of the proposed project, including location of all activities, timing, all works and activities, camp, fuel, waste, and transportation details, supported by maps.
- Discussion of alternatives to and alternate means of undertaking the development.
- Description of the biophysical environment that could be impacted by the development.
- Description of traditional and other land uses, harvesting areas.
- Description of the mitigations to be applied to reduce potential effects to the biophysical and human environment, including draft environmental management plans.
- An evaluation of the potential effects and cumulative effects of the project, and a summary of monitoring programs
- Detailed summary of engagement, issues and concerns raised and how the project addressed the issues and concerns.
- Description of how traditional knowledge has been used in the project proposal.

The NIRB will request additional information until the project proposal is deemed complete. At that time, a 45-day public comment period is initiated. During this time, the public may ask questions of the proponent. Once the NIRB has made its recommendation (assuming it recommends the project can proceed), the Minister of CIRNAC has 45 days to respond with a decision, with the option to extend for an additional 45 days.

3.1.2 Nunavut Water Board Amendment to Water Licence

The construction and operation of the new waste facilities will require an amendment to Arviat's type A water licence. An application to the Nunavut Water Board (NWB) can be made once the NIRB screening has been completed. A Type A water licence process takes approximately one year to complete from the time applications are filed, to issuance and as such, this process is one of the key considerations influencing construction timing.

At the time of application, plans and drawings are usually expected to be to 100% design development, and the project execution plan and schedule should be sufficiently developed to understand site-specific considerations during construction. Draft management plans previously used to support the NIRB screening can continue to be used as a basis to seeing regulatory approval. It is understood that at the time of application, it is unlikely that a contractor will have been selected to complete construction, and so certain assumptions will continue to be carried forward. Examples include site-specific spill-contingency measures and refueling practices. The licence application consists of a form, accompanied by supporting information such as management and monitoring plans and drawings. The approvals being sought must be within the scope, and consistent with, the project as screened by the NIRB. Key aspects of the water licence amendment application would include:

- Design drawings to 100% design development
- Operations and Maintenance Plan
- Spill Contingency Plan
- Hazardous Waste Management Plan
- Surface and Groundwater Monitoring Plan

The NWB review process for a type A water licence includes a technical review and public hearing. During the technical review, the application is circulated to interested and potentially affected parties such as Inuit Organizations, federal and territorial government departments, co-management agencies and Hunters and Trappers Organizations for comment. During this process, information requests can seek further information from GN-CGS as proponent. The technical review phase can include a technical meeting, during which outstanding issues are discussed with the intent of resolving them. Following the technical meeting, the NWB will determine if it has sufficient information to proceed to a public hearing. The NWB must provide 60 days' notice of a public hearing.

During the public hearing, the proponent (GN-CGS) presents their project, and other interested or invited parties make representations of their outstanding issues, resolved matters and recommendations for the NWB's consideration. The public hearing is a formal proceeding during which NWB board members have opportunity to ask questions of the proponent and parties to complete their evidentiary record. Once the hearing is complete, the NWB will render a decision on the requested amendment, along with the renewed/amended licence, inclusive of new conditions. The licence and reasons for decision are sent to the Minister of CIRNAC for approval within 9 months of the initial application being made by the proponent. The Minister can only sign or not sign the licence and has up to 90 days to do so.

The amended licence will contain terms and conditions for conducting, monitoring, and reporting associated with the new waste facilities. It would be expected that certain conditions would pertain to the submission of final management plans for approval 60 days prior to construction, as well as conditions for requiring submission of additional plans, such as an Interim Closure and Reclamation Plan.

3.1.3 Fisheries and Oceans Canada Request for Review

Fisheries and Oceans Canada (DFO) is responsible for reviewing proposed activities for potential to cause harmful alteration, destruction, or degradation (HADD) of fish or fish habitat. Owing to the proximity of the WWTF to potential fish habitat, DFO has a specific process, separate to the water licence review process for evaluating potential HADD of fish or fish habitat. A request for review (RFR) form, with all project design details and mitigations proposed to prevent or mitigate for HADD is submitted with the RFR form. If DFO is of the opinion that the project would not likely cause HADD of fish or fish habitat, it will issue a Letter of Advice with its views and specific mitigations it feels necessary. A finding that a HADD would be likely would require Fisheries Authorization to be acquired. Through site selection and effective mitigations, the new waste facilities (and in particular the WWTF) should not require a Fisheries Authorization.

3.1.4 Archaeological Impact Assessment

An Archaeological Impact Assessment (AIA) will be required to be completed for all areas to be impacted by the new waste facilities, unless previously assessed. A class 1 archaeology permit would allow assessment and documentation of areas by a qualified archaeologist prior to ground disturbance. Archaeology permit applications must be received by March 31 of each year for assessment in snow-free conditions in the same year. If the AIA were to identify a direct conflict between a waste site and an archaeological site, the need to further document or remove artifacts under class 2 permit would be discussed with GN-Heritage.

3.1.5 Transport Canada Approval

The Arviat Airport Zoning Regulations (AZR; SOR /90-793) enacted under the federal *Aeronautics Act*, are intended to prevent lands within 4 kilometres (km) of the airport from being used in a manner that is not compatible with the safe operation of an airport or aircraft. The Arviat AZR specify limitations on elevations of buildings, structures, and objects within different zones. The waste facilities are within the outer surface zone and therefore subject to the AZR. Arviat AZR do not require completion of an Airport Bird Hazard Risk Assessment (ABHRA), but it is understood that GN-CGS has completed one for each of the facilities, out of due diligence to address risk to aircraft from the new waste facilities. Several approvals are required to construct and operate *each of* the new waste facilities within the outer surface zone, and this may include an exemption to the AZR if the specified elevations are to be exceeded for any aspect of the proposed developments. The exemption to the AZR, if required, requires the following to be completed to support the request, for *each of* the new waste facilities:

- NAV Canada Land Use Approval
- GN-EDT Letter of “No Objection”

- Hamlet of Arviat Council Motion to support project sites
- Transport Canada Exemption Application Package and Fee

Regardless of whether exemption to the AZR is required, the NAV Canada Land Use No Objection Letter, GN-EDT Letter of No Objection and Arviat Council Motion are required for *each of* the facilities. These are described further below.

NAV Canada Land Use No Objection Letter

A Land Use approval, in the form of a Letter of No Objection from NAV Canada, is required to conduct any new land use activity within the outer surface zone that includes erection of a new structure. NAV Canada will review the details of the proposed structure to confirm whether it conforms to the AZR – specifically the proposed structure's impact on air navigation system and installations. Design information showing location and dimensions of all structures is required to complete the application form – one per facility. The application should also indicate whether an exemption to AZR is being sought.

GN-EDT Letter of No Objection and Arviat Hamlet Council Motion

If an AZR exemption is required, and to support both of the NAV Canada Land Use applications, the airport operator (GN-EDT), must indicate in writing that they do not object to the location, type, and operation of *each of* the facilities being proposed. GN-EDT should base its determination on the preliminary drawings and ABHRA. The outcome of this step is a letter indicating "no objection" to the specific facility that is the subject of the Land Use, and if applicable, AZR exemption application.

In addition to GN-EDT, the Hamlet of Arviat must also approve the location of each of the proposed waste facilities. This would be expected to be done during a council meeting, where the outcome would be a Motion to approve the location of the proposed facility. To date, an official motion to investigate Sites 1 and 13 for a lagoon system has been approved. This will be revisited at the business case presentation to the Hamlet prior to entering into the detailed design phase of the project.

Application to Transport Canada (if required)

The application to Transport Canada for exemption to the AZR (if required) is a letter request, accompanied by an aeronautical obstruction clearance form and all supporting documents, as detailed above. During the review, Transport Canada may request additional information, and may also engage specialists for their review. A positive outcome of the request for exemption is a letter specifying the exemption to the AZR for the proposed subject facility, along with any conditions, including specific operations, mitigation, or monitoring requirements.

3.1.6 Amendment to Zoning By-Law

Depending on the location of the new waste facilities an amendment to the Arviat Zoning By-Law No. 207 may be required to permit the specified type of land use (per Section 6, Zone Regulations). The amendment will require that an application for such amendment be brought before Hamlet Council for consideration. It is suggested that candidate sites will have previously been reviewed with councilors during the feasibility stage so that there is approval-in-principle before a by-law amendment is sought.

3.1.7 Use of Land Within 100 feet of Ordinary High-Water Mark

The coastal zone within 100 feet (approximately 30 m) of the ordinary high-water mark is administered by the federal or territorial commissioner of lands. The Nunavut Agreement includes that this land may be used for the sole benefit of the Municipality. The care and control of this land, if to be used for either of the new waste facilities should be transferred to the Hamlet of Arviat. The process for this is not specified in the Nunavut Agreement. This should be the subject of further discussion with Crown Indigenous Relations and Northern Affairs Canada and GN-CGS, beginning with written notification of intended use of the 100-foot strip for the sole benefit of the Municipality.

4. CAPACITY ASSESSMENT

The capacity analysis will ultimately provide the information to determine the size requirements for a new WWTF.

The section will include:

- Design year;
- Population projection;
- Flow projections; and
- Raw wastewater qualities.

4.1.1 Population Projection

Arviat population was estimated to be 2,657 residents in 2016 (Statistics Canada 2016).

Population projections conducted by the Nunavut Bureau of Statistic (NBS) are available for the period between 2014 and 2035 for the Hamlet of Arviat (Nunavut Bureau of Statistics 2014) and will be used for the present project. However, since the projections produced by the NBS end in 2035, the annual growth rate between 2034 and 2035 (1.735%) will be used to complete the projection until the end of the design horizon, which is 2040. The design horizon is the period used to establish the capacity requirement for a facility, which is 20 years for both sewage lagoons and mechanical plants according to CSA W203:19 and the Good Engineering Practice for Northern Water and Sewer Systems (referred to as the Good Practice hereafter) published in 2017 by the Department of Municipal and Community Affairs (MACA) of the Government of the Northwest Territories, resulting in a design year of 2040. Growth rates and population are presented in Table 4-1.

Table 4-1: Growth Rates and Population of the Hamlet of Arviat for the Period from 2016 to 2040

Year	Annual Growth Rate	Population
2016	-	2,737
2017	2.440%	2,804
2018	2.364%	2,870
2019	2.327%	2,937
2020	2.347%	3,006
2021	2.290%	3,075
2022	2.202%	3,143
2023	2.154%	3,210
2024	2.027%	3,275
2025	1.977%	3,340

Year	Annual Growth Rate	Population
2026	1.935%	3,405
2027	1.834%	3,467
2028	1.766%	3,528
2029	1.737%	3,590
2030	1.727%	3,652
2031	1.740%	3,715
2032	1.732%	3,780
2033	1.735%	3,845
2034	1.751%	3,912
2035	1.735%	3,980
2036	1.735%	4,049
2037	1.735%	4,120
2038	1.735%	4,191
2039	1.735%	4,264
2040	1.735%	4,338

As indicated in the table, the design population to be serviced by the wastewater treatment and disposal system is 4,338 people in 2040.

4.1.2 Wastewater Volume Projections

According to the CSA W203:19 and the Good Practice, the total community water use (TCWU) is composed of two components:

- Residential water use (RWU), and
- Non-residential water use (NRWU; i.e., commercial, institutional, etc.).

Since the Hamlet is serviced through a trucked sewage system, the volume of RWU per capita can be assumed to be 90 Lpcd according to the CSA W203:19 and the Good Practice. Historical records can be used to estimate the extent of the non-residential component of the TCWU. Table 4-2 shows the historical water trucking records for the TCWU for the period between 2016 and 2019. The values indicate an average TCWU of approximately 100 Lpcd, which suggests an NRWU of about 10 Lpcd. A TCWU of 100 Lpcd will be used in this study.

Table 4-2: Recorded Water Consumption from 2016 to 2019

Year	Actual Water consumption (m^3)	Population (Capita)	Total Community Water Use (Lpcd)
2016	97,685	2,657	100.73
2017	98,751	2,724	99.31
2018	103,521	2,793	101.54
2019	104,606	2,864	100.07

The Hamlet has upgraded its water treatment and delivery system to improve the distribution of the treated water to the water users. It is expected that the TCWU will reach 105-110 Lcpd.

In this study, the wastewater generation rate will be conservatively assumed to 90% of the water consumption rate. I.e. 90% of the drinking water will end up in the wastewater holding tank and the wastewater treatment system.

The average daily sanitary wastewater generation rate (Q_a) can be calculated with the following formula:

Q_a = TCWU X 90% × Population

Given a population of 4,338 in 2040,

Q_a = (100 Lpcd × 4,338 capita) ÷ 1,000 = 434 m^3/d.

The active storage volume required for 10 and 12 months of can be calculated as per the following:

Active storage volume required for 10 months of storage = 434 × 365 × 10 = 1,584,100 m^3

Active storage volume required for 12 months of storage = 434 × 365 × 12 = 1,900,920 m^3

4.1.3 Raw Wastewater Qualities

As the historical raw wastewater quality data is unavailable, the following wastewater quality data are reviewed to estimate the raw wastewater qualities to the proposed wastewater treatment system:

- Load values from published literature;
- Wastewater Engineering Treatment and Resource Recovery, 5th edition, Matcalf & Eddy 2014;
- Wastewater quality data from Canadian national standard – CSA W203:19, Planning, design, operation, and maintenance of wastewater treatment in northern communities using lagoon and wetland systems; and
- Raw sanitary wastewater quality test results from similar communities

The textbook *Wastewater Engineering Treatment and Resource Recovery, 5th edition* (Metcalf & Eddy 2014) gives typical loads range per capita in the wastewater discharged from residences. Based on the loads per capita, considering the water use rate in Arviat, the corresponding wastewater quality range is shown in Table 4-3.

Table 4-3: Typical Raw Wastewater Quality Range

Parameter	Concentration Range
cBOD, mg/L	500 – 1,200
TSS, mg/L	600 – 1,500
Totan Ammonia Nitrogen (TAN), mg/L	50 – 120

Parameter	Concentration Range
TKN, mg/L	90 – 220
Total phosphorus (TP), mg/L	27-45

The raw wastewater quality from two communities, Cape Dorset and Pangnirtung, with the similar lifestyle in the similar climate condition are presented in Table 4-4.

Table 4-4: Raw Wastewater Quality in Communities Similar to Arviat

Parameter	Cape Dorset	Pangnirtung
cBOD, mg/L	435	470
TSS, mg/L	165	360
TAN, mg/L	122	122
TKN, mg/L	77	95
TP, mg/L	14	14
Alkalinity, mg/L	357	392
pH	7.3	7.4

CSA W203:19 standard is widely accepted and specifically for northern communities' trucked system with recommended wastewater quality values available in Table 4-5.

Table 4-5: CSA Typical Wastewater Quality for Northern Trucked System

Parameter	Concentration Range
cBOD, mg/L	450
TSS, mg/L	400
TKN, mg/L	100
TP, mg/L	15
E. Coli (CFU/ 100 mL)	10^7 – 10^8

By comparing the wastewater quality data from three sources, it is found the values based on Metcalf & Eddy publishing are extremely high compared to the other two sources. The reason might be because of the relatively low water use in Arviat used in the calculation of concentrations. The CSA standard recommended qualities are closed to the test results from the two communities. The wastewater quality in the in Table 4-5 is deemed reliable and will be adapted in the Hamlet of Arviat wastewater treatment system design.

5. TECHNOLOGY ASSESSMENT

5.1 TREATMENT TECHNOLOGY OPTIONS

5.1.1 Lagoon System

Northern condition often requires a different approach to design than what is commonly used in Southern Canada where the ground, climate and logistics are different. Therefore, wastewater treatment systems in Northern communities always have Northern specific challenges, conditions, and considerations.

Practically, wastewater treatment facilities are characterized in two categories, mechanical treatment plant and lagoon/wetland system. As mentioned, consultation with the Hamlet indicated a strong preference for a lagoon system. Though both types of treatment are discussed within this section, the options for lagoon system will form the basis of evaluation and recommendation. The basic elements of lagoon system design have remained unchanged for decades. However, the aspects of the basic designs have evolved, and some modifications have been developed and adopted in recent years. These have been in response to increasingly stringent water quality regulatory requirements for point source discharges.

The major procedures, processes, and design methods relevant to wastewater treatment lagoon will be. The basic types of lagoon are listed in below.

- Anaerobic Lagoon;
- Facultative Lagoon; and
- Aerobic Lagoon.

In different applications, lagoons are designed to enhance the growth of natural ecosystems that are either anaerobic, aerobic, or facultative which is a combination of the two. Lagoons are managed to reduce concentrations of BOD, TSS and Coliform numbers to meet discharge criteria. Table 5-1 summarizes information on lagoon application, loading and size for wastewater.

Table 5-1: Basic Wastewater Lagoon Specifications

Lagoon	Application	Typical cBOD Loading (kg/1000m^2/d)	Typical Detention Time (d)	Typical Depth (m)	Remarks
Anaerobic	Industrial Wastewater	280 - 4500	5 - 50	2.5 – 4.5	Subsequent treatment normally required
Facultative	Raw municipal wastewater, or effluent from primary treatment, trickling filters, aerated	22 - 56	7 - 50	0.9 – 2.4	Most commonly used wastewater treatment lagoon.

Lagoon	Application	Typical cBOD Loading (kg/1000m^2/d)	Typical Detention Time (d)	Typical Depth (m)	Remarks
	lagoons, anaerobic lagoons				
Aerobic	Generally used to treat effluent from other processes. Produces effluent low in soluble cBOD and high in algal solids	112 - 225	2 - 6	0.18 – 0.3	Maximize algae production; algae are harvested for nutrient removal

Note: Specifications adapted from EPA/600/R-11/088

5.1.2 Mechanical Wastewater Treatment Facilities

Due to the complexity of operation and costs, it was determined at an early phase of the project that a mechanical WWTF would not be encouraged for Arviat. At the Hamlet council meeting in August, all members had a strong opinion with preference unanimous for a passive (lagoon) WWTF. The discussion within this section is to provide information for mechanical WWTF options for Arviat, however, have been presented for information purposes only. Only the passive WWTF options will be ranked within this business case.

A mechanical treatment plant will need to produce high quality effluent based on the technology-base limits. To meet the high-quality effluent standard, the following four mechanical wastewater treatment technologies were preselected as the candidate technologies for the Hamlet:

- Conventional Activated Sludge (CAS) process;
- Membrane Bioreactor (MBR) process;
- Moving Bed Biofilm Bioreactor (MBBR) process; and
- Sequencing Batch Reactor (SBR) process.

5.1.3 Disinfection

5.1.3.1 Chlorination/Dechlorination

Sodium hypochlorite, a liquid chlorine solution commonly known as bleach, is widely used in wastewater treatment disinfection. A typical liquid hypochlorite chlorination system includes solution tank(s), metering pumps, chemical tubing, diffuser (to inject the solution into the water) and contact tank to allow the reaction time to inactivate the bacteria. A building to house the equipment is normally required. Sodium hypochlorite solution is metered into the wastewater effluent and the chemical is allowed to work in the contact tank for the duration of the design contact time. Leftover chlorine remaining in the wastewater effluent is toxic to aquatic life and must be removed to prevent impact on aquatic life in the river. Sodium bisulfate is typically used for residual chorine removal. Sodium hypochlorite can be delivered in liquid form or be generated on-site. On-site generation requires solid salt delivery. Due to the CCME requirements of having less than 0.02 mg/L total residual chlorine at the compliance point, de-chlorination must be implemented after chlorination. However, de-chlorination chemicals are also hazardous in nature and can have detrimental effects to the receiving environment. Furthermore, controlling total chlorine residual to below 0.02 mg/L is extremely challenging and pose a high risk of noncompliance. Therefore, chlorine disinfection for this application is not recommended.

5.1.3.2 Ozone Disinfection

The components of an ozone system include feed-gas preparation, ozone generation, ozone contacting, and ozone destruction.

To generate ozone, air or pure oxygen is used as the feed-gas source and pass to the ozone generator at a set flow rate. The energy source for production is generated by electrical discharge in a gas that contains oxygen. The extremely dry air or pure oxygen is exposed to a controlled, uniform high-voltage discharge at a high or low frequency.

After the ozone is generated, it is fed into a down-flow contact chamber containing the wastewater to be disinfected. The main purpose of the contactor is to transfer ozone from the gas bubble into the bulk liquid while providing sufficient contact time for disinfection. Because ozone is quickly consumed, it must be contacted uniformly in a near plug flow contactor.

The off gases from the contact chamber must be treated to destroy any remaining ozone before release into the atmosphere.

The major issue of ozone system is the very high capital cost and operation cost, especially the high demand of electricity and expensive spare parts. It also requires commercial liquid oxygen which makes it difficult to use in Northern Canada. Therefore, it is <u>not</u> recommended for Arviat.

5.1.3.3 UV Disinfection

An ultraviolet light (UV) disinfection system is a physical process that transfers electromagnetic energy from a mercury arc lamp to an organism's genetic material and result in inactivation of the microorganisms. The main components of a UV disinfection system are mercury arc lamps, a reactor, and ballasts.

The source of UV radiation is either the low-pressure or medium-pressure mercury arc lamp with low or high intensities. Submerged quartz tubes must be routinely removed and cleaned of surface deposits of metal salts and absorbed organics that block UV transmission. Cleaning consists of dipping the quartz tubes in a low strength acid and wiping them down. Most UV systems have the option of installing an automatic wiper that will mechanically clean the quartz tubes on regular intervals. This does not eliminate the need to clean them by hand, but it significantly reduces the frequency.

Lamp and ballast replacement are necessary every year to maintain adequate UV intensity. Typically, spent UV bulbs are returned to the UV bulb suppliers for proper disposal.

5.1.4 Solid Processing/Management

All mechanical treatment plants will produce solid wastes as by-products of the wastewater treatment process, which is called sludge. Typically, there are two sources of sludge produced from the plant, primary sludge from headworks and secondary sludge from secondary treatment. In many wastewater plants, the primary sludge and secondary sludge are combined and mixed together for treatment. The mixed sludge is therefore called biosolids.

Solids management can be classified into following areas:

- Solids thickening: Thickening is the process where water is removed from the solids and usually generate thickened sludge containing up to 4% total solids (%TS).
- Solids Dewatering: Dewatering is usually the next stage to further remove water and generate dewatered sludge containing approximately 20% total solids.
- Drying: Drying is a process whereby further reduces the water content of sludge by means of natural or thermal processes.
- Solids stabilization: Solids stabilization refers to the reduction of organic content and pathogen levels in the biosolids.

5.1.4.1 Thickening/Dewatering

Thickening/Dewatering reduces sludge disposal costs because of volume reduction and less hauling. Dewatering systems use mechanical forces to reduce the moisture content of biosolids. The performance of the technology is highly dependent on the characteristics of the feed stock (i.e., aerobically digested sludge versus anaerobically digested sludge). Proper chemical conditioning prior to mechanical dewatering is often required to improve the dewaterability and achieve the desired solids content of the final product. Dewatering processes that are commonly used include: centrifuge, screw press, belt filter press, filter.

5.1.4.2 Freeze/Thaw Dewatering

Freeze/Thaw dewatering works on the principle that when sludge freezes, water molecules crystallize which forces the solids and other impurities out to the boundary of the ice crystal, where they become compressed or dehydrated (Metcalf and Eddy, 2003). During the thaw period, meltwater drains away freely through the network of channels between the consolidated particles, leaving a dewatered sludge. Simple gravity meltwater drainage during the thawing stage can reduce the volume of sludge by 85 to 96%, leaving a sludge cake ranging from 20% up to 82% solids. Sludge freeze-thaw beds together with a storage facility, such as a lagoon, tank, or digester to store the sludge in summer, can be used as the sole method of dewatering in cold regions.

5.1.4.3 Drying

Drying is a process that reduces the water content of sludge by means of natural or thermal processes. In natural drying (air drying), sludge is spread in open air for a considerably long time to evaporate the water by ambient heat and draining of water due to gravity. The effectiveness of this process depends on the local climate. Natural drying will occur faster in warm and dry weather. Thermal drying involves the application of heat to evaporate water and reduce the moisture of biosolids, producing dried biosolids that can be utilized as a soil amendment or potential fuel. Heat-dried biosolids reduce the mass of biosolids by a factor of approximately 6 because they contain less water, significantly reducing hauling costs, and improving storage capacity. Many types of dryers are available, providing several options. Both indirect and direct dryers are often used for drying of municipal biosolids.

5.1.4.4 Solid Stabilization

Sludge stabilization is a process to reduce the organic materials in the sludge before going to the dewatering or other treatment steps. Sludge stabilization is generally achieved by digestion with two (2) types of processes:

- Anaerobic digestion; and
- Aerobic digestion.

Anaerobic digestion is the process in which organic materials in an enclosed vessel are broken down by micro-organisms, in the absence of oxygen. Anaerobic digesters can be operated at temperature of 35°C (mesophilic) or at 55°C (thermophilic). Anaerobic digestion produces biogas (consisting primarily of methane and carbon dioxide) as by-products. Anaerobic digestion systems are also often referred to as "biogas systems." If the biogas is not utilized, open flaring is required. Aerobic sludge digestion is a biological process that takes place in the presence of oxygen. With oxygen, bacteria present in the sludge (activated sludge) consumes organic matter and converts it into carbon dioxide. Aerobic digestion is energy intensive and as such generally utilized at smaller wastewater treatment facilities only.

5.1.5 Mechanical Treatment Facilities Precedents in Northern Canada and Other Arctic Climate Locations

As a reference, this section gives an overview of mechanical treatment plants in Northern Canada. Historically, Northern communities have treated wastewater with passive WWTF rather than mechanical WWTF. Many mechanical WWTFs have experienced numerous problems largely related to the complexity of the system and operational requirements. Some other causes of problems include improper design to suit Northern conditions, unproven technology selection, poor operation and maintenance, and poor contract administration issues. Table 5-2 shows a summary of the mechanical plants in Canada North with reported performance and challenges.

Table 5-2: Northern Canada Mechanical Wastewater Treatment Plant Experience

Location	Observations
Pangnirtung, Nunavut	Original facility based on Rotating Biological Contactor (RBC) technology was commissioned in 2004. Multiple mechanical failures observed after starting up. This was considered due partly to the under-sizing. Subsequently upgraded to a Membrane Bioreactor (MBR) based technology. Process units included screening, MBR and Geotube technology was selected for solids management.
Iqaluit, Nunavut	Original lagoon treatment system was upgraded to an MBR based secondary treatment in 1997. Construction was never completed due to contract enforcement weaknesses. The system was undersized and poorly constructed. Subsequently primary treatment was upgraded based on Salsnes Filter technology. Secondary upgrade is in progress based on MBBR technology with solids dewatering utilizing Belt Filter Press technology.
Rankin Inlet, Nunavut	This is only a primary treatment facility. Originally commissioned in 1996 with Rotating Drum Filter technology. Numerous issues mainly due to the too small screen opening size (0.3 mm). Oil and Grease accumulation was also an issue. Subsequently upgraded to larger screen opening size, include automatic hot-water and surfactant screen washing system.
Fort Simpson, NT	Originally commissioned in 2002 with a proprietary technology. Did not meet the performance criteria resulting in number of litigations. Subsequently upgraded to Sequencing Batch Reactor (SBR) technology with screening and flow equalization and has been operating satisfactory since.
Carmacks, Yukon	Original facility was built in 1975. Converted into extended aeration facility in 2009. There were number of coordination issues with number of contracts. Resulted in significant delays and additional costs. At the end there were significant deficiencies with respect to documentation and SOPs.
Dawson City, Yukon	Originally in 2002 proposed SBR based technology and was not pursued due to high O&M costs. In 2008 aerated lagoon technology-based system was proposed however not pursued due to land-use issues. In 2009, design build contract was awarded, and a system based on Aerated Deep Shaft technology. The system was started in 2012. The performance has been inconsistent and incurred very high O&M costs.

In addition to the Northern Canada, published information of a number of other Arctic climate wastewater treatment practices were reviewed, and a brief summary of the findings can be listed below:

- In Northern Quebec – Mostly wastewater treatment lagoons (aerated lagoons),
- In Siberia – Mostly conventional activated sludge based mechanical wastewater treatment,
- Northern Europe – Mostly conventional activated sludge based mechanical wastewater treatment followed by chemical nutrient removal, and
- In Alaska – Many medium to large communities are serviced by mechanical wastewater treatment that provide only preliminary and primary treatment. Some facilities have secondary treatment with conventional biological wastewater treatment. Majority of smaller communities utilize wastewater lagoons.

A list of available Alaskan mechanical facilities is listed in Table 5-3.

Table 5-3: Summary of Alaskan Mechanical Wastewater Treatment Facilities

Location	Process	Capacity
Soldotna WWTP	Filter screen + Grit removal + Extended Aeration Activated Sludge process + Secondary Clarifier + UV disinfection + Aerobic Digestor + Belt press	1.2 million gallons per day
City of Wrangell WWTP	Screen + Trickling Filters + Aeration Basin (conventional biological treatment)	1.8 million gallons per day
Petersburg Borough	Rotating Screen + Grit removal + Primary Clarifier + Solid landfill	2.1 million gallons per day
Municipality of Anchorage WWTP	Screening, Grit removal, Sedimentation, Skimming, and chlorination. Sludge from the primary clarifiers is thickened and dewatered +landfill	154 million gallons per day
Golden Heart Utilities	Screens and micro-screens and Primary treatment and Secondary treatment	8 million gallons per day
Charcoal Point WWTP, city of Ketchikan	Screening, Grit removal, Primary sedimentation, Sludge from the primary clarifiers is thickened and dewatered by belt press + Solid landfill	4 million gallons per day

In summary, most common technology for wastewater treatment in rural communities in the Arctic is wastewater lagoons. Medium to large communities use mechanical wastewater treatment facilities based on conventional biological wastewater treatment or at minimum primary treatment (screening and grit removal).

5.2 RECOMMENDATION ON PREFERRED TECHNOLOGY

5.2.1 Lagoon

5.2.1.1 Comparison

Each type of lagoon has its' own advantages and disadvantages. The requirements and efforts of design, construction, O&M are all different. Specific considerations and limitations applicable to the site should be taken in technology selection. Table 5-4 lists the comparison between different lagoons.

Table 5-4: Lagoon Comparison

Type	Advantage	Disadvantage
Anaerobic Lagoon	Sludge removal is infrequently needed. 80 – 90% cBOD removal can be expected. Energy requirements to run the plant are low or none. Operation and maintenance are relatively uncomplicated.	Not designed to produce effluent that can be discharged. The lagoon can emit unpleasant odors. The rate of treatment is dependent on climate and season.
Facultative Lagoon	Infrequent need for sludge removal. Effective removal of settleable solids, cBOD, pathogens, fecal coliforms, and a limited extent of NH_3. Easy to operate and require little energy.	Higher sludge accumulation in shallow lagoons. Variable seasonal NH_3 in the effluent. Emergent vegetation must be controlled to avoid creating breeding areas for mosquitoes and other vectors. Shallow lagoons require relatively large areas.

Type	Advantage	Disadvantage
		During spring and fall climatic turnover, odors can be an intermittent problem.
Aerobic Lagoon	Reliable cBOD removal. Significant nitrification of NH_3 possible with sufficient mean cell resident time. Treatment of influent with higher cBOD in less space. Reduced potential for unpleasant odors.	More complicated to design and construct. Mechanical aeration equipment may be required. Increased capital and O&M costs. A larger staff is needed, and training must be provided on a regular basis. Sludge removal is more frequent and requires off-site treatment for disposal.

5.2.1.2 Other Considerations

In addition to above descripted advantages and disadvantages, there are other parameters to consider in lagoon technology selection. Typically design criteria, performance, operation and maintenance and costs are the main aspects to be carefully studied. **Appendix C** presents further information on these considerations.

5.2.1.3 Conclusion and Recommendation of Technology Selection

By comparing the three major types of lagoons in all aspects entailed above, in the effort of minimizing mechanical equipment, limiting the land use and excavation to a lower extend and the complexity of the system, considering the nature of the severe climate and geographic location of Arviat, it is recommended to upgrade the existing lagoon to a facultative lagoon system with lining inside to prevent exfiltration. The configuration of the lagoon would be multiple cells setup in parallel with aeration cells in front to deal with variable loads of organic in spring when the frozen water in the lagoon started to thaw. This setup of the system has longer detention time, more resilient operation in summer and winter, higher contaminant removal, less requirement of close monitoring and lower capital costs, etc.

5.2.2 Mechanical Wastewater Treatment Facility

It is understood that implementation of a mechanical WWTF for Arviat has been strongly discouraged by the Hamlet. Sections 5.1.2 to 5.1.5 clearly outline the processes required for a mechanical WWTF and the substantially high O&M requirements. This section has been formulated for information purposes or in the event that that decision changes.

Except for the secondary treatment technologies, other treatment components are straight forward to select for the application in Arviat.

- Truck unloading station: Mandatory.
- Coarse screening: Mandatory.
- Primary treatment: Mandatory. Screening combined with primary clarification is recommended.

- Flow equalization: Mandatory.
- Secondary Treatment: Mandatory.
- Disinfection: Mandatory. UV disinfection is recommended.
- Solids handling process and disposal: Mandatory. The proposed WWTF is relatively small and will not expect a large amount of sludge. The recommended technology is using freeze/thaw dewatering method. Compared to mechanical sludge thickening and centrifuge dewatering, freeze/thaw method costs substantially less in equipment and system procurement and daily operation. It also requires less effort and skills to do the daily maintenance.

Secondary treatment process selection is elaborated in following sections.

5.2.2.1 Secondary Process Selection Criteria

Four technologies were preselected in Section 5.1.2. To determinate the most suitable technology for Arviat, detailed selection criteria is developed. Nunami Stantec assigned integer scores for the criteria ratings to indicate the relative degrees of preference with higher scores indicating improved benefit. The rating scores used in the analysis are: 10 points, 5 points, and 1 point. This tool is primarily used for comparative analysis for planning and feasibility studies. Table 5-5 defines the ratings for each selected criterion.

Table 5-5: Evaluation Criteria for Secondary Treatment

Evaluation Criteria	Description		
	10 Points	5 Points	1 Point
Development	Established	Innovative	Emerging
Relative Treatment Efficiency	Higher	Equal / Intermediate	Lower
Reliability	Yes	Somewhat	No
Robustness	Yes	Somewhat	No
Resiliency	Yes	Somewhat	No
Future Proofing	Yes	Somewhat	No
Footprint	Smallest	Moderate	Largest
Energy consumption	Lowest	Moderate	Highest
Chemical/Ballast Use	Smallest	Moderate	Extensive
Complexity Simple Moderate Complex	Simple	Moderate	Complex
Staffing Requirements	Existing Staff		More qualified staff
O&M Cost	Lowest	Moderate	Highest
Capital Cost	Lowest	Moderate	Highest
Visual Impacts	Minimum	Moderate	Maximum
Odor Issues	Minimum	Moderate	Maximum
Noise Pollution	Minimum	Moderate	Maximum

Evaluation Criteria	Description 10 Points	5 Points	1 Point
Local Job Creation	High	Moderate	Low

The secondary treatment will be reliably maintained compliance with the current Water Act License effluent limits and focused on technologies that consumes less energy, maximize the use of local resources, and reduces environmental impacts.

The secondary treatment system rating scores are available in Table 5-6.

Table 5-6: Secondary Treatment System Rating Scores

Evaluation Criteria	SBR	MBR	MBBR	CAS
Development	10	10	10	10
Relative Treatment Efficiency	5	10	5	5
Reliability	10	10	10	10
Robustness	10	5	10	10
Resiliency	10	10	10	5
Future Proofing	5	10	10	1
Footprint	5	10	5	1
Energy consumption	10	1	10	5
Chemical/Ballast Use	10	1	10	5
Complexity Simple Moderate Complex	10	1	5	10
Staffing Requirements	5	1	1	10
O&M Cost	5	1	5	10
Capital Cost	10	1	10	5
Visual Impacts	10	10	10	5
Odor Issues	10	10	10	5
Noise Pollution	10	10	10	10
Local Job Creation	5	5	5	5
Score	**140**	**106**	**136**	**112**

5.2.2.2 Conclusion and Recommendation of Technology Selection

As it shows, SBR and MBBR obtain approximately same scores in Table 5-6. Because of high capital cost, most complex setup, and high skills requirement to staff, MBR has been ruled out of being an option for Arviat.

SBR and MBBR are advantageous over conventional activated sludge reactors as they usually require less space, resilient to load and flow fluctuations, consume comparatively less energy and lower capital cost.

The two technologies will be further reviewed in the schematic design for final selection.

Figure 5-1 shows a conceptual process flow diagram and recommended technologies.

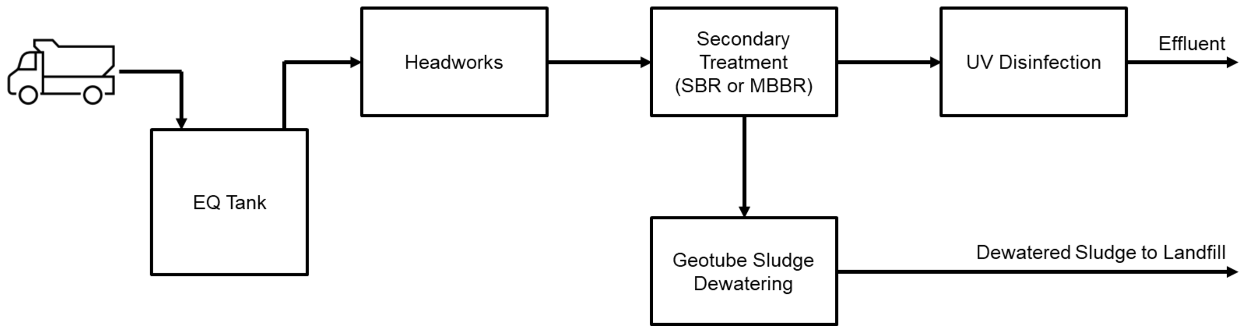

Figure 5-1: Recommended Process Flow Diagram

5.3 UPGRADE OPTIONS COMPARISON

The most common technology for wastewater treatment in rural communities in the Arctic is wastewater lagoons for their relatively low capital cost, simple operation, and acceptable treatment results. Medium to large communities use mechanical wastewater treatment facilities. Given the remote location of the Hamlet, construction and operation of a mechanical plant will be challenging. With many moving parts and electrical components, e.g., blowers for the bioreactors, pumps for water transfer, fans for ventilation, motors for driving the blowers etc., highly skilled operators are needed as outsourcing the maintenance and repair work in an emergency occasion is not practical in this remote hamlet.

The Hamlet encouraged this project to proceed forward with a lagoon system. Nunami Stantec agrees that the Hamlet should select the wastewater lagoon as the treatment technology in its wastewater treatment and disposal.

6. SITE SELECTION

6.1 DESKTOP REVIEW OF ALL SITES

Though separated into two business case reports, both solid waste and wastewater site selection were considered together. This site selection analysis was required in order to identify potential viable areas having the capacity to host a new WWTF, and in consideration of appropriate land to host a new solid waste management facility (SWMF). The following sections provide information regarding the overall selection process, key selection criteria, as well as a summary description of site characteristics specific to a shortlist of potential sites.

A significant amount of work has been conducted between 2008 and 2010 in relation with the development of a new SWMF in Arviat, which formed the basis of the desktop review. Included as part of previous studies was the identification and evaluation of potential candidate sites (Nuna Burnside 2008). As both WWTF and SWMF could affect the same locations, previously identified sites have been carried over and further evaluated. Only those sites relevant for the WWTF will be discussed and evaluated within this document.

6.1.1 Site Selection Process

Likely one of the most important factors in the development of a new WWTF is related to the selection of the land on which the facility will be developed. This step-by-step approach involves considering several natural, social, economic, and technical factors. It is therefore based on the adequate balance between these factors that the efficiency of the new WWTF could be evaluated in the future.

Key steps in the site selection process are summarized as follow:

1. Determining site selection criteria;
2. Developing a list of candidate sites;
3. Gaining better understanding of local site conditions through a desktop assessment and a reconnaissance site visit;
4. Filtering through candidate sites falling short of key selection criteria (i.e., initial site selection phase); and
5. Conducting final site selection based on a quantitative assessment of multiple criteria (site selection matrix).

Information related to each of those steps is provided in the following sections.

6.1.2 Selection Criteria

The selection process required the development of defendable selection criteria. Because an unsuitable lagoon site may generate negative environmental, social, and/or economic impacts, it is important that a credible site selection process accounts for all those factors.

For the initial site selection phase, key selection criteria included the following:

- Located within the Hamlet limits;
- High proportion of slopes under 10%;
- Overall land suitability and absence of adverse terrain conditions, constraints and geohazards (e.g., steep slopes, gullies, seepage areas, features indicative of ice-rich permafrost, etc.); and
- Appropriate distance from natural landscape elements.

Other criteria considered during the site evaluation process included:

Main criteria:

- Length of new access road required;
- Appropriate distance from existing and/or planned infrastructures and public utilities (e.g., drinking water catchment locations, existing water treatment facilities[1], etc.);
- Respect of valued land areas which aim to protect historical, cultural, and recreational elements of the community (e.g., traditional cultural heritage sites, hunting and fishing sites, potential park); and
- Requirement of preparation works (e.g., rock blasting).

Secondary criteria:

- Available area;
- Linear distance from the Hamlet;
- Respect of the 4 km airport exclusion zone[2];
- Surficial material and drainage;
- Slope
- Area disturbance;
- Proximity of local borrow material;

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[1] Public Health Act, General Sanitary Regulations, R.R.N.W.T. 1990, Section 28c
[2] Arviat Airport Zoning Regulations, SOR/90-793.

- Overall site visibility (i.e., from main roads, community, and airport industrial area);
- Respect of the 300 m buffer distance from buildings used for human occupancy and/or the storage of food[3];
- Respect of the 30 m buffer distance from public road allowance, railway, right of way, cemetery, or thoroughfare[4];
- Potential impacts of prevailing winds.

The selection criteria description and values are available at Table 6-1. It should be noted that secondary criteria are rated on a scale of 0 to 3 and, main criteria, because of their importance, rated on a scale of 0 to 6. For main and secondary criteria, a score of 0 depicts an important constraint.

Table 6-1: Selection Matrix Criteria Description and Values

Main Criteria	Criteria Value			
	0	2	4	6
Available area	≤ 8.5 ha	N/A	≥ 7.5, ≤ 8.5 m²	≥ 8.5 ha
Capacity	No capacity for existing or future requirements	Capacity for existing, but not future	Capacity for future growth, 10 months	Capacity for future growth, 12 months
Hamlet preference	Rejected	Not ideal	N/A	Preferred
Length of new access road required	≥ 4 km	≤ 1 km and existing access road requires major upgrade	≤ 1 km and existing access road requires minor upgrade	Adjacent to
Appropriate distance from existing infrastructures	Within the freshwater river catchment area	Non-respected	N/A	Respected
Airport distance & bird migration	Within 4km radius, and change to current bird patterns with obvious impact to runway	Within 4km radius, and change to current bird patterns	Within 4km radius, but no change to current bird patterns	Outside 4km radius
Respect of valued areas	Close to important valued areas	Non-respected	Problem with public perception	Respected
Preparation works	Extensive works (Blasting)	Important	Limited	None
Disturbance area	Undisturbed (Valued area)	Undisturbed (Non-valued area)	Proximity to an existing access road	Already disturbed
Secondary Criteria	**Criteria Value**			

[3] Public Health Act, General Sanitary Regulations, R.R.N.W.T. 1990, Section 28b
[4] Public Health Act, General Sanitary Regulations, R.R.N.W.T. 1990, Section 28a

	0	1	2	3
Linear distance from the Municipality	≥ 20 km	> 10 km	> 5, ≤ 10 km	≤ 5 km
Linear distance from airport	≤ 4 km and inside the flight path	≤ 4 km	> 4 to ≤ 6 km	> 6 km
Airport distance & bird migration	Within 4km radius, and change to current bird patterns with obvious impact to runway	Within 4km radius, and change to current bird patterns	Within 4km radius, but no change to current bird patterns	Outside 4km radius
Surficial material and drainage	N/A	Organic and/or high surface seepage and/or poor drainage	Granular materials with some organic and/or surface seepage	Granular materials and/or bedrock outcrops
Slope	N/A	> 25 %	> 5 %, ≥ 25 %	≤ 5 %
Availability of local borrow material	No material on site, no borrow area at proximity (> 10 km)	Limited material on site, borrow area at proximity (≤ 10 km)	N/A	Material available on site
Overall site visibility	N/A	Visible from the community and the main road	Non-visible from the community, visible from the main road	Non-visible from the community and the main road
300m buffer distance from buildings used for human occupancy	Non-respected (Exemption not possible)	Non-respected (Exemption possible)	Restriction for future expansion	Respected
30m buffer distance from public road allowance	Non-respected (Exemption not possible)	Non-respected (Exemption possible)	N/A	Respected
Availability of a wetland treatment area	No wetland treatment area considered	30% of required surface area	70% of required surface area	100% of required surface area
Discharge point utilization/construction	Construct new discharge point	Utilizing existing discharge point with major upgrade	Utilizing existing discharge point with minor upgrade	Utilizing existing discharge point
Aesthetic issues (odor, impacts of prevailing winds, etc.)	Unfavorable (Winter and summer)	Unfavorable (Winter or summer)	N/A	Favorable

6.1.3 Review of Background Information

A review of background information was conducted, as part of the site selection process, to describe baseline site conditions (i.e., physiography, bedrock and surficial geology, climate, and permafrost conditions) and to identify potential constraints that could pose a challenge to the construction, operation, and/or maintenance of the proposed new WWTF.

Background data was collected from a variety of sources including (but not limited to) the following:

- Digital Elevation Data (DEM)[5];
- 2019 satellite imagery from ESRI service Layer[6] and Google Earth;
- Arviat vector base data (hydrology, topography, land parcels and infrastructure)[7];
- Digital surficial geology (Hodgson 2003; GSC 2014) and bedrock geology (St-Onge et al. 2007; Belley et al. 2017) mapping; and
- Literature and reports on terrain and overall permafrost conditions in the area (Heginbottom and Radburn 1992; Manley 1996; Leblanc et al. 2015; CDG 2019; CSA PLUS 4011:19)

Relevant information gathered from previous geotechnical site investigations conducted in Arviat was reviewed and summarized in the document *Geotechnical Investigation Report – Wastewater and Solid Waste Planning Study, Arviat, NU (final, April, 2021)* prepared by Nunami Stantec as part of this study.

6.1.3.1 Physiographic Setting and Landforms

The Hamlet is located within the Kivalliq Region of Nunavut, more precisely along the west coast of Hudson Bay. The global impact of repeated Quaternary glaciations is one of the main drivers responsible for the distinctive landscapes and landforms present throughout the area. At a regional scale, the area surrounding Arviat consists of a flat to very gently undulating plain where topography barely exceeds 25m above sea level (asl) within the first 10 km from the shoreline. Within the community itself, most infrastructure was developed in areas with natural grade ranging between 2 and 10m asl.

The local landscape is characterized by a mosaic of small lakes and ponds, most of which are shallow and occupy low-lying terrain located between glacially formed gravel ridges interpreted as drumlins (or flutes) and eskers. These drumlins (mainly located west of the community) were carved by the east-trending icesheet during and after the last glacial maximum (Forbes et al. 2014). Two major east-west oriented eskers are crossing the developed portion of the community. One matches the location of Arviat itself along the southern shore of the harbor, and a second parallel one (referred as the Airport or Airstrip Esker) is intersected by the airport's runway and terminates into the Hudson Bay further

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[5] ArcticDEM data acquired online at https://www.pgc.umn.edu/data/arcticdem/.
[6] Service layer credits: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, AeroGRID, IGN, and the GIS User Community
[7] Data provided by the Government of Nunavut, Department of Community and Government services.

east towards the southern edge of the peninsula. Note that several other eskers are present within the municipal boundary limits further to the north and south, several of which represent potential prospect sites for aggregate sourcing.

Another glacially related landform present in the area consists of raised beach-ridges. These features are related to the isostatic rebound (uplift) and shoreline emergence that followed the recession of the icesheet after the last glacial maximum (James et al. 2011, Simon et al. 2014). An example of raised beach deposits includes the area immediately south from the current landfill.

6.1.3.2 Bedrock

The Hamlet of Arviat lies within the Western Churchill Province of the Canadian Shield, more precisely within the Hearne domain, an area composed predominantly of Archean igneous and metamorphic rocks (Tella et al., 2007). The igneous rocks include tonalite and granodiorite while the metamorphic rocks comprise various metasedimentary and metavolcanic rock types. A review of available satellite imagery and mapping data suggest that bedrock is only rarely exposed in the area, limited to a few locations including along the coastline, near the south end of the airport's runway as well as further north and west of the Hamlet.

6.1.3.3 Surficial Geology

Information relevant to surficial geology is available through several publications including, but not limited to, the following:

- Arsenault et al. 1981;
- Aylsworth and Shilts 1989;
- Forbes et al. 2014; and
- Digital surficial geology mapping data available through Canadian Geoscience Maps 240 and 241 (GSC 2017a and GSC 2017b).

Based on the above-cited references, the dominant surficial deposit type present within Arviat's municipal boundary limits consists of marine intertidal sediments deposited prior to the post-glacial isostatic rebound (see polygons labeled as "Hm" on Figure 6-1 below). The composition of this material mainly consists of poorly sorted stony silt and sand with pockets of sorted nearshore sand and gravel and marine clayey silt.

Other key materials include glaciofluvial sand and gravels (Pgf) which compose the various eskers and other outwash deposits located alongside some of the eskers. This material is commonly used as fill material within the community. Marine nearshore or tidal deposits (Hmt) are present along the current shoreline and consist of a mixture of silt, sand, and gravels. It is in those deposits that are found the raised beach deposit testifying of previous sea-levels. Further inland to the west, ice-contact deposits (glacial till) is present over much of the landscape. This material ranges from a thin-veneer overlying bedrock, to a thicker blanket in areas characterized by flutings and drumlins. Till generally comprises a poorly sorted diamicton with a silty matrix.

More recent Holocene deposits present in the area include wetland deposits consisting of organic-rich mud (Hw) and peat (Ho), as well as aeolian dunes (He) consisting of sand. These wind-blown deposits are rather rare and limited to areas located alongside the esker, east of the current landfill and lagoon sites.

Surficial materials present at the current wastewater and solid waste management facilities consist mainly of glaciofluvial sand and gravels. Immediately south from the landfill and lagoons, the wetland treatment area is located on material accumulated on raised beach deposits (silty sand to gravelly sand). These materials are poorly drained which contributed to the accumulation of organic soils. The thickness of the organic soils is expected to range from 0.2m to maximum of approximately 1m.

Further north at the bulky metals waste area, surficial materials consist of a mixture of silty fine sand, with variable fractions of clay and fine gravels. These materials are associated to a former marine tidal environment.

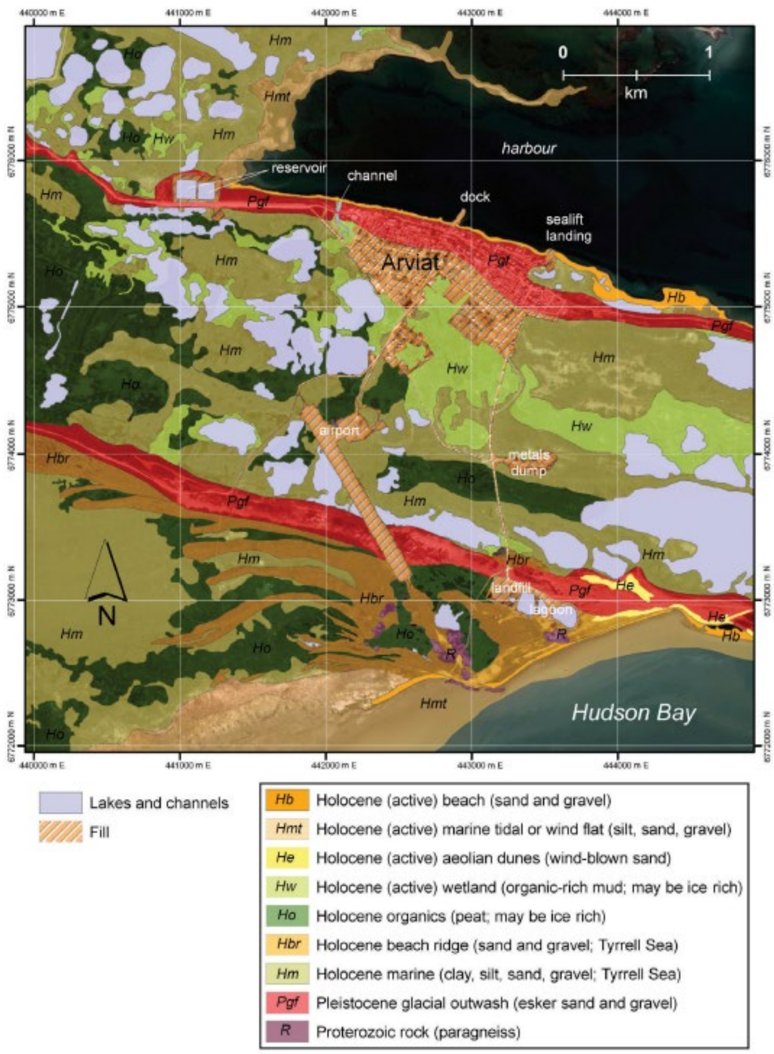


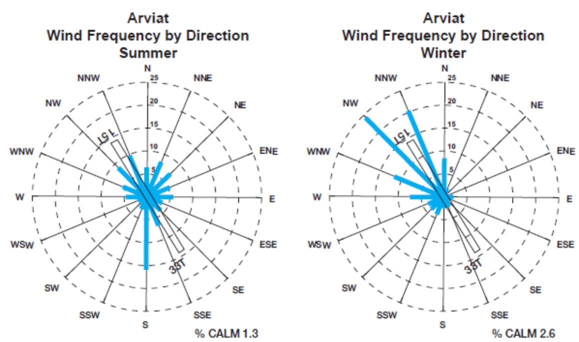
Figure 6-1: Arviat – Surficial Geology (Forbes et al. 2014)

6.1.3.4 Climate and Environment

Arviat is located within the Southern Arctic ecozone portion of the northern Kivalliq, a region characterized by large areas of exposed, sparsely vegetated terrain in association with discontinuous shrub tundra vegetation classified as having a low arctic ecoclimate (Campbell et al., 2012). The climate is described as cold and dry, with mean daily temperatures from 11°C in July to -29°C in January. The mean annual air temperatures (MAAT) were about -9.3°C. The average thawing and freezing indices are 981°C days and 4291°C days, respectively. The total annual precipitation was 286 mm, of which 112 mm (39%) fell as snow (Canadian climate normals, 1981–2010[8]).

Air temperatures in the Arctic have warmed at approximately twice the global rate for several decades (Anisimov et al., 2007). During the 1981-2014 period, MAAT at the Municipality of Rankin Inlet (located approximately 210 km north) rose about 2°C at an average rate of 0.068°C yr^{-1} and similar trends were observable at Arviat (Tremblay et al., 2015). Based on a low greenhouse gas emissions scenario (RCP 4.5), it is projected that the MAAT in Arviat will show an increase of approximately 2.3°C from 2021 to 2050[9].

The regional setting makes that the climate is moderated by the open waters of Hudson Bay during the late summer and early fall prior to freeze-up when damp foggy weather is common. Winds from the north-northwest and northwest generally prevail, both in frequency and in strength. Refer to Figure 6-2 for the wind roses and wind table associated to data recorded at the Arviat airport facility (Nav Canada 2003).



Percent wind 20 knots and greater																Arviat
DIRECTION	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N
SUMMER	0.8	0.4	0.4	0.2	0.1	0.2	0.1	0.4	0.0	0.0	0.0	0.2	0.9	1.9	1.9	0.5
WINTER	0.1	0.1	0.2	0.4	0.3	0.1	0.7	0.8	0.2	0.1	0.1	0.2	1.0	5.6	4.2	0.9

Figure 6-2: Arviat – Wind Frequency by Direction (NavCanada 2003)

Additional wind and weather analysis data is available from a snowdrift assessment (RWDI 2009) conducted in support of a proposed landfill access road (Dionne Road area). Results of this assessment are in accordance with Nav Canada data, which detail the prevailing action of north-northwest and northwest wind. Following acceptance of this draft report, Nunami Stantec will be coordinating a new snow and wind study with RWDI, which will be appended in the final document submission.

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[8] https://climate.weather.gc.ca/climate_normals/
[9] https://climateatlas.ca

6.1.3.5 Permafrost and Periglacial Features

Based on regional permafrost zonation, the region falls within an area of continuous permafrost, where low to moderate ice content is generally expected (Brown et al., 2002). High ice content permafrost is likely to occur in wetland deposits comprising organic-rich mud and peat. Local permafrost is assumed to be saline in relation to the position of Arviat along the low-lying shoreline terrain bordering of the Hudson Bay, as the area was submerged by the Tyrell Sea following the last glacial maximum (Hivon and Sego, 1994; Forbes et al., 2014).

Mean Annual Ground Temperature

Mean annual ground temperature (MAGT) were not available for Arviat. Based on an empirical relationship and MAAT of -6.8°C (2009-2010), an approximate MAGT of -4°C at 10 to 15 m bgs can be estimated. MAGT from Rankin Inlet were also reviewed and used as a support reference. Tremblay et al. (2015) reported MAGT varying from -8°C to -9°C at 30 m bgs in the year 1960 and MAGT varying from -7°C to -8°C at 16 m bgs in the year 1998. More recent published data for the year 2017, reported average summer ground temperatures of -5.6°C at 12 m bgs for a site on developed land and -6.6°C at 7 m bgs for a site on undeveloped land (Oldenborger et al., 2017).

Active Layer

Based on Shilts et al. (1976), the thickness of the active layer (i.e., the top layer of soil subject to annual thawing) varies from 0.5 m in poorly drained organic-rich deposits, to 1.5 m or more in well drained outwash sediments. An active layer depth of approximately 1.2 m and groundwater table at approximately 0.4 m were measured within the wetland treatment area, south of the lagoon site (Nuna Burnside, 2010). It should be noted that active layer depths are dependent on many site-specific variables such as surficial material, ground disturbance, vegetation and snow cover, drainage, soil moisture content, MAAT, topography, and sun exposure.

Permafrost Warming

Climate is the principal factor controlling the formation and persistence of permafrost. As the climate warms, shallow permafrost is also expected to warm (CSA PLUS 4011:19). Permafrost warming can lead to a deepening of the active layer and thawing of permafrost ground ice. The loss of volume caused by the melting of ground ice generates settlements and subsidence.

It is well recognized that permafrost degradation can adversely affect buildings with shallow foundations (e.g., settlements and cracking) and/or provoke localized settlements and subsidence.

The presence of pore water salinity induces freeze point depression. The freezing point depresses approximately 0.28°C for every 5 ppt of salinity. Hence, soils with a pore water salinity of 32 ppt will have an actual freeze/thaw temperature of about -2°C. Hivon and Sego (1993) reported pore water salinities ranging between 0.8 to 38.3 ppt in Arviat.

A review of open-source satellite imagery suggested the presence of thaw-sensitive permafrost features in the area. An example is the presence of ice wedge polygons (i.e., ground ice feature that result from the thermal contraction of permafrost soils, creating cracks that fill with ice formed from snowmelt water) within the imperfect to poorly drained terrain (generally organic-rich), located to the southwest of the current SWMF and old lagoon (Figure 6-3).

Figure 6-3: Example location of ice wedges polygons in low-lying terrain southwest from the current site

6.1.3.6 Landscape Hazards and Terrain Constraints

Landscape hazards, or geohazards, are geological conditions that may lead to localized or widespread damage to property and threaten personal safety. Constraints are terrain characteristics or features that are likely to pose a challenge to the construction, operation, or maintenance of infrastructures relative to future site development. Their identification is essential to assess for the overall suitability of an area for future development.

Information relevant to landscape hazards and other terrain-related constraints in Arviat is available from publications by Forbes et al. (2014) as well as Flynn et al. (2019). These studies were developed in support of climate change adaptation planning and provide site specific information related to local terrain conditions (e.g., surficial deposits, permafrost, and ground ice, etc.). A landscape hazard map produced as part of the above-cited studies is presented in Figure 6-4.

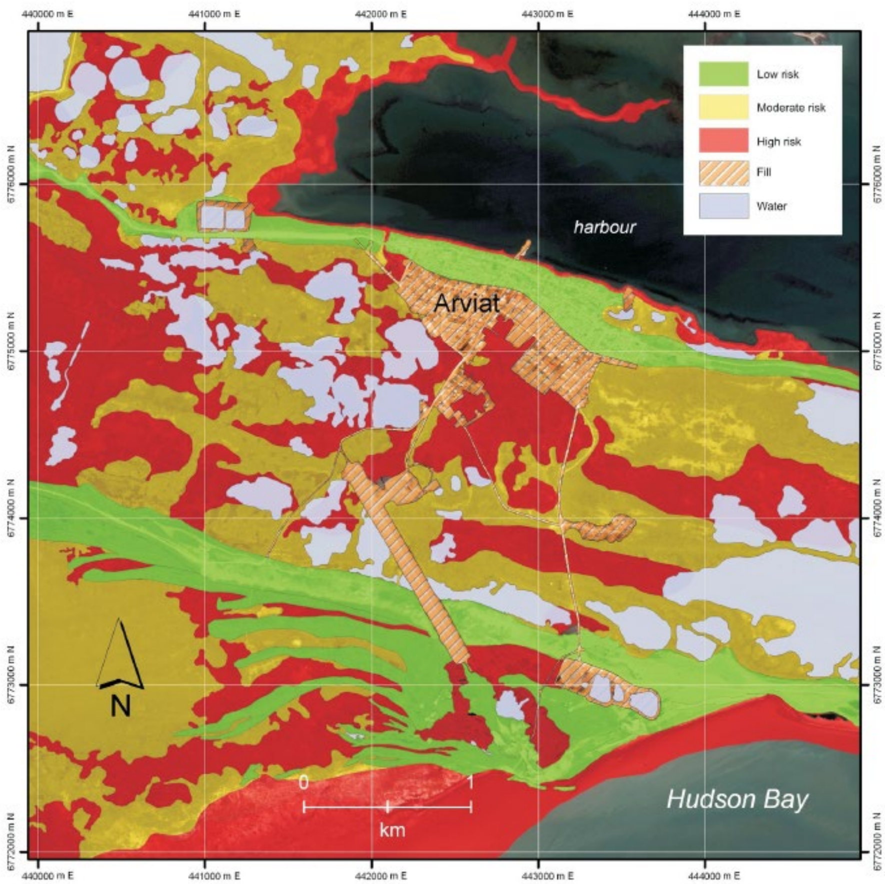

Figure 6-4: Preliminary landscape hazards map for Arviat (Forbes et al. 2014)

6.1.3.7 Climate Change

As previously indicated, additional information regarding climate change, how it could affect the community and how locals could develop adaptation measures is available through the Climate Change Adaptation Action Plan (CCAAP) that was develop for Arviat (Nasmith and Sullivan. 2010).

The following consist of a summary of key hazards and/or constraints having the potential to impact the development and operation of the new proposed facilities. These elements will need to be considered as part of the design of the new waste facilities.

- Presence of fine-grained marine soils;
- Presence of ice-rich permafrost susceptible to differential thaw settlement;

- Presence of organic soils, including areas of high-centre polygons;
- Presence of poor surface water drainage throughout the community (even in areas built on fill) as well as in undeveloped areas surrounding the community; and
- Presence of issues related to foundation stability (e.g., frost jacking, thaw settlement, differential movement of piles and possible instability related to saline permafrost).

Issues related to the above-listed items are expected to be intensified due to impacts of climate change. Expected impacts (some already occurring) include the following:

- Increased ground temperature, thawing of ground ice and increased of the active layer thickness;
- Increased surface water ponding in low lying areas;
- Increased potential for flooding and erosion;
- Deterioration of transportation infrastructures (roads and runways);
- Increased ground subsidence beneath and/or around buildings;
- Increased frost jacking of piles;
- Increased issues related to coastal changes (e.g., potential hazards associated with storm surge and wind-driven waves in summer);
- Potential for contamination of surface water around the existing or future waste disposal areas; and
- Potential for localized slope failure.

Sea-level Projections for Five Pilot Communities of the Nunavut Climate Change Partnership (James and al. 2011) indicates that, in contrast to the picture of rising sea levels and coastal inundation that is frequently painted in popular reports, future sea levels may follow a very different trajectory featuring stable or even falling sea level for some communities in Nunavut. This is a consequence of two factors.

1. Over much of Nunavut, the land is rising, owing to the delayed response of the Earth to surface unloading caused by deglaciation. Rising land ameliorates the effects of rising global sea levels. Some areas, such as eastern Baffin Island and the western Arctic, are subsiding and this is a potential issue as it would exacerbate possible sea-level rise; and
2. Owing to their relative proximity to potentially large sources of meltwater (Arctic ice caps and the Greenland ice sheet), sea-level fingerprinting is very important in determining sea-level projections for communities in Nunavut.

Sea-level fingerprinting has the effect of muting or even reversing the sea-level rise produced by regional sources. This is in contrast to regions that are distant from large sources of meltwater, where an amount of sea-level rise close to that delivered to the global oceans would be expected.

An assessment of probable range of sea-level change for five (5) communities incorporating uncertainty in vertical land motion between 2010 and 2100 is available in Table 6-2.

Table 6-2: Probable Range of Sea-level Change Incorporating Uncertainty in Vertical Land Motion in Five (5) Nunavut Communities (2010-2100)

Community	Sea level will probably not be less than (cm)	Sea level will probably not be more than (cm)
Arviat	-70	25
Whale Cove	-75	20
Kugluktuk	-10	50
Cambridge Bay	-35	50
Iqaluit	0	70

In the event where a location for a new WWTF is identified close to the costal line, it is expected that the sea level will probably not rise more than 25 cm limiting the risks to the infrastructure.

In addition to the effects of sea-level change, coastal stability is influenced by the frequency and intensity of extreme events, such as major autumn storms. Indirectly, changes to the extent and duration of sea-ice, such as the time of autumn freeze-up, can also make the coastline more (or less) susceptible to storms. Long-term coastal stability should be accounted for during the site selection process.

6.1.4 Initial Candidate Sites Selection

6.1.4.1 Areas of Interest and Existing Access Road Infrastructures

The following section summarizes site conditions at key areas of interest surrounding the developed portion of the community. Note that most of this information was originally compiled by Nuna Burnside as part of site selection activities (including community consultations) conducted in 2008.

Refer to the following report for additional details:

- Selection of a New Municipal Solid Waste Disposal Site and Access Road Arviat, Nunavut. Nuna Burnside. October 2008.

Three distinct areas of interest where identified (Figure 6-5).

Figure 6-5: Site Selection – Areas of interest

<u>Dionne Road area:</u>

The Dionne Road runs west from the Hamlet towards Dionne Lake and provides access to interior lands. This site was only considered for the solid waste portions of this work, not for wastewater.

<u>West Road area:</u>

The West Road is a small road used to access aggregate resources from an esker south and west of the airport and provides recreational access to interior lands west of the Hamlet. The preliminary desktop study suggested that the eskers mapped along this road would be suitable for a SWMF. Though less suitable for a WWTF, Site 13 (Table 6-3) is included within this zone, just south west of the runway.

Upon closer inspection with Hamlet staff, the area was found to be flat, low-lying, wet, and prone to extensive seasonal overland flooding. The small elongate eskers rising a few meters above the plain were of insufficient size to host a landfill site. The access road between the eskers was low-lying and prone to flooding. The small esker located between 3 km and 4 km has been partially used for borrow material and is too close to the airport.

The small esker between 5 km and 6 km is narrow and consists of fine to medium sand. It is not large enough to host a WWTF and the entire area around is low, wet, flat lying, and seasonally flooded. The small esker beyond 8 km was also unsuitable for the same reason. Significant importation of locally scarce aggregate would be required to construct an access road to the area. The local esker material is too sandy for road construction in this area.

The land around the West Road is very flat, wet, and low lying. The surface is wet organic soil and prone to extensive seasonal sheet flooding. No suitable area could be located within the initial 8 km length of the West Road and does not represent the optimal location for a lagoon system running farther west. Access road construction and maintenance to this area would be expensive, however, Site 13 remains a possible site.

Maguse River Road area:

The Maguse River Road leads from the Hamlet to the Maguse River, approximately 20 km from the Hamlet. It forks off the Dionne Road just past the water reservoir and trends north-westerly. The initial 4 km is partly within the aircraft flight path, and the terrain is characterized by many small ponds and low-lying areas.

Between 4 km and 6 km along the road, there are scattered small glacial deposits among ponds and small lakes. The area has many recreational cabins located on the high points, and Hamlet staff indicated this is a very popular area for recreation and would likely not be approved for the construction of a SWMF or WWTF.

At approximately 4 km, a small road branches west from the Maguse River Road, past several cabins located south from Landing Lake. The road follows a poorly defined, low-lying, and discontinuous esker for approximately 3.5 km. Constraints to landfill sitting includes the presence of cabins as well as poorly drained low-lying area.

A small road branches off the Maguse River Road just before 6 km and travels east along a small esker bordering a series of small lakes. Many cabins are located along the road and there is insufficient area to site a landfill.

At approximately 6 km along the Maguse River Road, the road narrows to a causeway between a small lake and a deep bay. The road goes up and down a series of small hills, and Hamlet staff indicated drifting snow makes the road impassable in the winter.

At approximately 6.5 km the road crosses a small bridge. The bridge is unsuitable for all-season continuous use by a garbage truck. Between the bridge and approximately 7.5 km, the road consists of a boulder-based causeway between the lake and the bay. Hamlet staff indicated it is flooded in the spring and impassable for up to a month. The road is unsuitable for all-season garbage truck traffic.

Beyond 8 km the area is low-lying for some distance. Additional discontinuous esker ridge segments are located in the area (e.g., west of route km 8 and west route km 10); however, these eskers are too narrow and low-lying to be considered as viable sitting locations for the development of a landfill.

Finally, although a larger, more suitable esker is located along Maguse River Road near the north end of Arviat Municipal Boundary, the 20 km distance of the site from the community makes that developing and operating a landfill anywhere in the area would be cost prohibitive. The only site suitable for a WWTF on this road would be Site 12, which is currently used as a quarry site. This site becomes unfavourable considering the community activity around this location on land, and the proximity of the community marine port to the required discharge location.

6.1.4.2 Proposed Candidate Sites

The initial list of potential candidate sites consisted of 14 locations. Most of these sites are located along the three areas of interest described in the previous section. Note that this list of candidate sites includes locations that had previously been identified and described by Nuna Burnside.

Baseline conditions at these sites were assessed using available documents and satellite imagery. The purpose of this exercise was to summarize baseline conditions (e.g., topography, land use, physical and environmental conditions) and identify potential constraints that could affect the development and operations of new SWMF or WWTF. Observations made from the review of available satellite imagery are in accordance with the information compiled from the review of existing documents. Of all the sites considered for this project, only Site 1 (existing lagoon and SWMF), Site 6, Site 7, Site 8, Site 12, and Site 13 would be possible for a WWTF and discharge.

Figure 6-6 shows the location of all numbered sites considered in the desktop review.

Table 6-3 summarizes key site characteristics at the initial candidate sites.

Figure 6-6 Desktop Site Selection (All Sites)

Table 6-3: Key Site Characteristics at the Initial Candidate Sites

Site	Surficial material or landform	Surface elevation and slopes	Potential for geotechnical issues	Access to site	Proximity to stream and waterbodies	Distance from Airport
1	Marine sediments (raised beach deposit)	Approx. 10 m above low-lying terrain Mostly 0-2%, up to 8% further south from the lagoon	Low No apparent constraint identified from desktop review	Existing road access	Ponds ~ 250m to the north	~1 km
6	River delta / marine shoreline Wetland	Low-lying terrain ~2m above sea level ~1% towards the ocean	Moderate to high due to required access road as well as local soil conditions.	Existing trail (~4.1 km) Approx. 4km of new road required	Proximity to Wolf River delta	~4.5 km
7	Marine nearshore sediments	Low-lying terrain Flat	Moderate due to seasonally high-water table	None Approx.0.8km of new road required		~2 km
8	Raised beach deposits surrounded by nearshore marine	Beach ridge is ~1 m above low-lying terrain. 0-2% slopes	Moderate due to seasonally high-water table. Flood potential	Existing trail (~1 km) Approx. 2km of new road required	Close proximity to waterbodies (within the 50m buffer)	~3 km
12	Nearshore marine deposit	Low-lying terrain Mostly 0-2 % slopes	Moderate due to poor Drainage condition and potential seepage	Approx. 600m of new road required	No stream or waterbodies within 300m.	~3.5 km
13	Esker ridge surrounded by low-lying marine sediments	Northern portion of the site is ~5 m above low-lying terrain	Low within the ridge area Moderate within the low-lying portion due to poor drainage and potential for ice-rich permafrost	Existing road access	Outside	~3.5 km

Table 6-4 summarizes pros and cons of the initial candidate sites.

Table 6-4: Pros and Cons at the Initial Candidate Sites

Site	Pros	Cons
1	Existing infrastructure/access Availability of local aggregate material Land already impacted by SWMF and WWTF activities **Hamlet preference**	Proximity to airport Limited area available for development Earthworks required to increase overall development area Proximity to airport
6	Distance from the community would limit potential impacts to traditional land use	Would require significant volume of fill to build site and road

Site	Pros	Cons
	Outside 4km airport buffer	Likely an environmentally sensitive location (estuarian area). Portion of the site is located within a wetland. Potential geotechnical challenges Currently unimpacted site **Rejected by Hamlet**
7	Close to community (low O&M cost)	Would require extensive fill placement (none at the site) Proximity to community, including cemetery Location within restricted development area (residential district) Downwind of community based on predominant wind direction Potential geotechnical challenges Proximity to airport **Rejected by Hamlet**
8	Relatively close to proximity (low O&M cost)	Seasonally high-water table and potential for flooding Would require extensive fill placement (none at the site) Site surrounded by open water Environmentally sensitive area (habitat for bears) Potential geotechnical challenges Negative impacts to community activities (i.e., whaling) Proximity to airport **Rejected by Hamlet**
12	Availability of local aggregate material	Site currently used as local borrow source; therefore, area might not be available Number of cabins near the site Site surrounded by waterbodies (potential environmental impacts due to seepage runoff) Site falls within airport departure / approach corridor Discharge may impact marine port Proximity to airport **Rejected by Hamlet**
13	Overall location present limited to no conflicts with identified constraints (aside from low-lying terrain conditions) **Approved by Hamlet as alternate location for investigation**	Seasonally high-water table Would require extensive fill placement Potential geotechnical challenges Proximity to airport

A series of figures were developed in support of the site selection process, which can be found in Appendix D.

6.1.5 Site Screening Process

On March 10, 2020, a meeting was held between CGS and Nunami Stantec to present the initial list of candidate sites. Specific goals of that meeting were to present the different sites, discuss some of their key characteristics, then identify pros and cons regarding the potential development of waste management facilities at these locations.

A results of that initial screening process was the elimination of candidate sites characterized by the presence of major constraint(s). Key constraints identified as part of this process included the following:

- Sites located within the 4 km airport exclusion zone;
- Sites which require the development of new access road (including river crossings); and
- Sites characterized by the presence of adverse terrain conditions (e.g., sites suspected to be subject to high seasonal runoff and/or poor overall drainage conditions, sites likely to contain thaw-susceptible permafrost).

On August 18, 2020, Nunami Stantec presented the site selection information for the SWMF and WWTF to the Arviat Hamlet Council, as well as the field plan for geotechnical investigation, topographic survey, and Phase I and limited Phase II Environmental Site Assessments (ESA). All sites, except for Sites 1 and 13 were rejected. A formal motion of approval was granted for Nunami Stantec to continue investigation at Site 1, and to investigate Site 13 as a backup.

Table 6-5 provides a summary of sites characterized by constraints. Only those considered as part of the WWTF business case are listed.

Table 6-5: Key Constraints Identified at the Candidate Sites

Candidate sites	4 km airport exclusion zone	Accessibility issues	Adverse terrain conditions	Comments
1	x			Preferred by Hamlet.
6		x	x	Rejected by Hamlet. Not suitable.
7	x			Rejected by Hamlet. Not suitable.
8	x	x		Rejected by Hamlet. Not suitable.
9				Rejected by Hamlet. Not suitable.
12	x			Rejected by Hamlet. Not suitable.
13	x	x	x	Hamlet agreed for this site to be considered as optional.

6.1.6 Reconnaissance Site Visit

6.1.6.1 Summary

A reconnaissance site visit was conducted in Arviat between August 13 to 20, 2020.

Upon arrival in Arviat, Nunami Stantec personnel contacted the SAO to initiate a discussion in relation to the SWMF and WWTF site selection process. Interview with members of the Hamlet provided mostly negative opinions regarding the establishment of either SWMF or WWTF on any sites outside of the existing site (Site 1). The main reasons were associated with community activity and a negative impact on Hamlet operations staff for sites farther away. There was also a strong rejection to considering a mechanical WWTF.

Sites 1 and 13 were confirmed to be the most reasonable sites for development by Nunami Stantec staff.

It should be noted that, following the geotechnical investigation, because the site was representing different characteristics, Site 1 was separated into two (2) distinct areas: Area A and Area B. A view of the two (2) areas at Site 1 are available at Figure 6-7.

Figure 6-7: Area A and Area B at Site 1

6.1.7 Final Site Selection

The final site selection process consisted of the following tasks:

1. Assessing site conditions at the three (3) remaining sites (Site 1 (Area A and B) and 13);
2. Assessing site conditions at the current WWTF; and
3. Completing the selection matrix.

The end-goal of this exercise was to assess and rank, through the evaluation of specific criteria, the sites that could support the development of a new WWTF.

6.1.7.1 Site Conditions at New Potential WWTF Sites

This section provides information on the potential new WWTF sites. Refer to Appendix A for the terrain maps and general characteristics of the sites.

Site 1 (Area A and Area B)

Site 1 is located in the area near the current landfill and sewage disposal facility. The elevation at the site ranges from approximately 8 to 13 m asl. The overall terrain consists of an esker ridge that rises about 6 m above the local terrain. Low-lying topography occurs in the northwest portion of the site within Area B. Characteristics of the site (Area A and B) are available in Table 6-6.

Area A is the land located directly east of the existing lagoon and utilized for Schematic Design Options 1 to 4. Area B is located north of the existing SWMF and lagoon and utilized for Schematic Design Option 5.

Table 6-6: Characteristics of Site 1 (Area A and B)

Description	Site 1 (Area A)	Site 1 (Area B)
Location (UTM 19)		
Site access	Existing road	Existing road
Distance from the airport	~ 0.5 km	~ 0.5 km
Distance from the Municipality	~ 2 km	~ 2 km
Area	4.0 ha	8.0 ha
Surficial geology	Sand with variable content of silt and gravel.	West portion: Sand with variable content of silt and gravel. East portion:

Description	Site 1 (Area A)	Site 1 (Area B)
		Sand with variable content of silt and gravel.
Slope	Generally under 5% and up to 20% along the southeastern edge of the esker ridge.	<u>West portion:</u> Generally under 2% and up to 25% along the depression side walls. <u>East portion:</u> Slopes are generally under 5% and up to 10% along the northern edge of the ridge.
Constraints and geohazards	Low ice content. Differential/localized thaw settlement potential is low. Localized poorly drained area within the westernmost portion of the site adjacent to the lagoon.	<u>West portion:</u> Moderate ice content. Differential/localized thaw settlement potential is moderate. Localized ponding. Near surface groundwater. <u>East portion:</u> Low ice content. Differential/localized thaw settlement potential is low. No localized ponding. Surface seepage or seasonally high-water table is expected in the area.
Environmental concerns NOTE	Area of potential environmental concern (APEC) 6: Five (5) soil samples were collected from this area and they did not exceed guidelines. Surface water and sediment samples were not collected from this area.	APEC 5: Of the two (2) surface water samples collected from this area, one (1) exceeded guidelines for copper and iron (Sample location SW-02) and both exceeded guidelines for fluoride (Sample locations SW-01 and SW-02). Fourteen (14) soil samples and two (2) surface water samples were collected from this area and did not exceed guidelines.

NOTE:

See the document Phase I and Limited Phase II Environmental Site Assessment Proposed Wastewater & Solid Waste Site (Site 1), Arviat, Nunavut – Draft (Nunami Stantec 2020) for more details.

Additionally, the document *Sewage Disposal Facility Report – Hamlet of Arviat* (Nuna Burnside 2010b) identified a wetland treatment area southwest of Site 1. Although close, Area A does not encroach on the wetland treatment area.

<u>Site 13</u>

Site 13 is located to the southwest of the community. The elevation at the site ranges from approximately 4 to 8 m asl. Characteristics of the site are available in Table 6-7.

Table 6-7: Characteristics of Site 13

Description	Site 13
Location (UTM 19)	441,490 E / 6,773,364 N
Site access	Existing road and trail access
Distance from the airport	~ 1.0 km
Distance from the Municipality	~ 2.1 km
Area	27 ha
Surficial geology	Nearshore marine deposits with beach crests slightly rising above the terrain and organic soils occur in the area. Likely to contain fine grained materials and organic soils.
Slope	Under 2%.
Constraints and geohazards	Moderately well to poorly drained. Potential for surface seepage with seasonally high-water table. Ponding occurs in the area. Ice wedges and high ice content permafrost. Differential/localized thaw settlement potential is high.
Environmental concerns	No area of potential environmental concern identified.

6.1.7.2 Site Conditions in the Area Near the Current SWMF and the Old Lagoon

Current SWMF and Old Lagoon

The current SWMF and the Old Lagoon are located southeast of the Municipality. The approximate elevation at the site is 10 m asl. Characteristics of the site are available in Table 6-8.

Table 6-8: Characteristics of the Current SWMF

Description	Current SWMF
Location (UTM 19)	443,319 E / 6,773,008 N
Site access	Existing road
Distance from the airport	~ 0.5 km
Distance from the Municipality	~ 2 km
Area	6.7 ha
Surficial geology	Reworked local material composed of sand with variable silt and clast contents, and municipal waste are buried.
Slope	Generally under 5%, with localized steeper slopes up to 25%.
Constraints and geohazards	No terrain stability issues nor permafrost-related constraints. Ponding occurs to the southwestern limit of the current SWMF.
Environmental concerns [NOTE]	APEC 1: From the surface water sample collected to the west of this area (Sample location SW-05), cadmium, copper, iron, zinc and chloride exceeded guidelines. From the sediment sample collected to the west of this area (Sample location SD-05) there was exceedances of modified total petroleum hydrocarbons (TPH) guidelines. No soil samples were collected from this area.

Description	Current SWMF
	APEC 2: From the surface water sample collected from this area (Sample location SW-03), cadmium, copper, iron and fluoride exceeded guidelines. From the sediment sample collected from this area (Sample location SD-07) there was an exceedance of modified TPH. No soil samples were collected from this area.

NOTE:

See the document Phase I and Limited Phase II Environmental Site Assessment Proposed Wastewater & Solid Waste Site (Site 1), Arviat, Nunavut – Draft (Nunami Stantec 2020) for more details.

Additionally, the document *Solid Waste Management Report – Hamlet of Arviat* (Nuna Burnside 2010a) identified a contaminant attenuation zone (CAZ) west of the current SWMF and the document *Sewage Disposal Facility Report – Hamlet of Arviat* (Nuna Burnside 2010b) identified a wetland treatment area southeast of the current SWMF.

Additional information relevant to the geotechnical properties of local soils are provided in the Geotechnical Investigation report produced by Nunami Stantec as part of this study.

6.1.8 Selection Matrix

The results of the selection matrix for the current lagoon site (Site 1, Area A and Area B) and 13 are available in Table 6-9. As all other sites have been rejected by the Hamlet, only Sites 1 and 13 will be considered. Table 6-1 shows the ranking criteria.

Table 6-9: Selection Matrix Criteria

Criteria	Current SWMF and Old Lagoon		Site 1 (Area A - Lagoon Options 1-4)		Site 1 (Area B - Lagoon Option 5)		Site 13 (Lagoon Option 6)	
Coordinates	61° 5'11.83"N, 94° 2'42.21"W		61° 5'17.68"N, 94° 2'21.15"W		61° 5'12.47"N, 94° 2'26.84"W		61° 5'31.17"N, 94° 5'29.28"W	
Available area	2.96 ha	0	≥ 8.5 ha	6	≥ 8.5 ha	6	≥ 8.5 ha	6
Capacity	No capacity for existing or future requirements	0	Capacity for future growth, 12 months	6	Capacity for future growth, 12 months	6	Capacity for future growth, 12 months	6
Hamlet preference	Preferred	6	Preferred	6	Preferred	6	Not ideal	2
Length of new access road required	Adjacent to	4	Adjacent to	6	Adjacent to	6	≤ 1 km and existing access road requires minor upgrade	4
Appropriate distance from existing infrastructures	Respected	6	Respected	6	Respected	6	Respected	6
Respect of valued areas	Respected	6	Respected	6	Respected	6	Respected	6
Preparation works	None	6	Important	2	Important	2	Extensive	0
Disturbance area	Already disturbed	6	Already disturbed	6	Already disturbed	6	Undisturbed	0
Main criteria - Subtotal		34		44		44		30
Distance from the community	< 5 km	3	< 5 km	3	< 5 km	3	< 5 km	3
Distance from the airport	< 4 km	1	< 4 km	1	< 4 km	1	< 4 km	1
Airport distance & bird migration	Within 4km radius, but no change to current bird patterns	2	Within 4km radius, but no change to current bird patterns	2	Within 4km radius, but no change to current bird patterns	2	Within 4km radius, and change to current bird patterns with obvious impact to runway	0
Surficial material and drainage	Reworked local material composed of sand with variable silt and clast contents and burned and buried waste	3	Sand with variable content of silt and gravel and is believed to present low ice content. Potential for differential thaw settlement is low in the area.	2	Sand with variable content of silt and gravel with near surface groundwater, localized ponding, and moderate ice content. Potential for differential thaw settlement is moderate in the area. Surface seepage or seasonally high-water table is expected in the area.	1	Likely to contain fine grained materials and organic soils, with near surface groundwater, localized ponding, and surface seepage with seasonally highwater table, ice wedges and high ice content permafrost	1
Slope	Generally under 5%	3	Generally under 5%	3	Generally under 5%	3	Generally under 2%	3
Availability of local borrow material	Limited material on site, borrow area at proximity (≤ 10 km)	1	Limited material on site, borrow area at proximity (≤ 10 km)	1	Limited material on site, borrow area at proximity (≤ 10 km)	1	Limited material on site, borrow area at proximity (≤ 10 km)	1
Overall site visibility	Visible from the community and the main road	1	Visible from the community and the main road	1	Visible from the community and the main road	1	Non-visible from the community, visible from the main road	2
300m buffer distance from buildings used for human occupancy	Respected	3	Respected	3	Respected	3	Respected	3
30m buffer distance from public road allowance	Non-respected (exemption possible)	1	Non-respected (exemption possible)	1	Non-respected (exemption possible)	1	Respected	3
Impacts of prevailing winds	Favorable	3	Favorable	3	Favorable	3	Favorable	3
Availability of a wetland treatment area	100% of required surface area	3	100% of required surface area	3	100% of required surface area	3	100% of required surface area	3
Discharge point utilization/construction	Utilizing existing discharge point	3	Utilizing existing discharge point with minor upgrade	2	Utilizing existing discharge point with minor upgrade	2	Construct new discharge point	1
Aesthetic issues (odor, impacts of prevailing winds, etc.)	Favorable	3	Favorable	3	Favorable	3	Favorable	3
Secondary Criteria Subtotal		30		28		27		27
TOTAL		64		72		71		57

Selection matrix scores, for main and secondary criteria, are available in Table 6-10.

Table 6-10: Selection Matrix Scores

Site	Option	Main	Secondary	Total
Current SWMF and Old Lagoon	Do nothing	34	30	64
Site 1 - Area A	1 to 4	44	28	72
Site 1 - Area B	5	44	27	71
Site 13	6	30	27	57

Scores, constraints (identified in the site selection matrix or previously in the report) and recommendations are available in Table 6-11.

Table 6-11: Scores, Constraints and Recommendations

Site	Score	Constraints	Recommendation
Current SWMF and Old Lagoon	64	A. Visual impact (Visible from the community and the main road). B. Non-respect of a 90m buffer distance from public road allowance. C. Impact of climate change: a. Greater polar bear observations both in and around the community; and b. Intensity of extreme events and impact on long-term coastal stability. D. Presence of areas of potential environmental concern (APEC 1 and 2).	Despite the high score, **the site (existing lagoon) is not recommended** as a stand-alone option as it does not fulfill current or future capacity requirements. Will be used in combination with Options 1 – 4.
Site 1 Area A	72	A. Potential for differential thaw settlement is high in the area. B. Visual impact (Visible from the community and the main road). C. Non-respect of a 90m buffer distance from public road allowance. D. Impact of climate change: a. Permafrost degradation; b. Greater polar bear observations both in and around the community; and c. Intensity of extreme events and impact on long-term coastal stability. E. Presence of areas of potential environmental concern (APEC 6).	Highest subtotal for the main criteria and highest score overall. **<u>The site is recommended.</u>** Consider all the constraints during the detailed design.
Site 1 Area B	71	A. Potential for differential thaw settlement is high in the area. B. Visual impact (Visible from the community and the main road). C. Non-respect of a 90m buffer distance from public road allowance. D. Impact of climate change: d. Permafrost degradation; e. Greater polar bear observations both in and around the community; and f. Intensity of extreme events and impact on long-term coastal stability.	Ranked just slightly below Site 1 Area A, meaning this could be utilized as an option if Site 1 Area A is not possible.

Site	Score	Constraints	Recommendation
		E. Presence of areas of potential environmental concern (APEC 5).	
Site 13	57	A. Likely to contain fine grained materials and organic soils, with near surface groundwater, localized ponding, and surface seepage with seasonally highwater table, ice wedges and high ice content permafrost. B. Impact of climate change a. Permafrost degradation; and b. Greater polar bear observations both in and around the community.	Lowest score. **The site is not recommended.**

6.2 RECOMMENDATION ON PREFERRED SITE

It is in our opinion that aesthetic pollution associated to wastewater treatment infrastructures are generally self-evident and, for that reason, the preference is generally to improve and/or expand current sites and avoid creating new disturbance in often currently untouched landscapes.

Based on the review of terrain conditions at the various sites, concerns expressed by community members concerning the construction of a new WWTF in several areas surrounding the Hamlet, discussions with the GN and results obtained from the selection matrix assessment, the preference is to utilize Site 1 and expand in surrounding terrain. Based on the observations made as part of the terrain assessment, Site 1 (both Area A & B) can be expanded to provide a lagoon with capacity for future growth. These options are discussed in Section 7.0 – Business Case Options.

In event where the Site 1 location could not be used or not selected by the GN or the Hamlet, Site 13 could be developed.

7. BUSINESS CASE OPTIONS

7.1 "*DO-NOTHING*" APPROACH

This approach is considered as a baseline scenario to forecast the future of the existing sewage disposal facility (as described in Section 2.2) in the event no funding is procured. Based on the information presented in the Project Background (Section 2.0), the following operational risks are anticipated to occur by year 2040.

The wastewater generation rate in 2040 is anticipated to be 434 m^3 based on a population projection of 4,338 capita and TCWU of 100 Lpcd. Given that the volume of the lagoon is 43,000 m^3, the hydraulic retention time will be about 143 days (less than 5 months). The lagoon should accommodate storage of wastewater, and precipitation, for at least 12 months to allow the treatment processes within the lagoon's ecosystem to effectively function, according to CSA W203:19. Therefore, it can be concluded that the available storage capacity of the existing lagoon will not be adequate, potentially resulting in reduced treatment capacity and deteriorated effluent quality. This is also evident from the current discharge practices being more frequent than annually and the water quality monitoring results being out of compliance with the water license.

In addition to the possible reduced treatment capacity of the lagoon, there is also a potential issue of a reduced treatment capacity in the wetland. This issue may occur as a result of the lagoon not having an adequate capacity to store sewage during the spring freshet with the release of thawing wastewater accumulated during the winter. This will result in reduced temperatures in the wetland which will negatively impact its functionality, especially the wetland's ecosystem will not likely be active yet to handle these discharges from the lagoon due to frozen soils.

Due to the aforementioned disadvantages associated with this approach, it will be excluded from further evaluation.

7.2 SCHEMATIC DESIGN OPTIONS

Six schematic design options are proposed for the two preferred locations, Site 1 and Site 13, as presented in Table 7-1. The layout design options are denoted as Options 1 to 5 for Site 1 and Option 6 for Site 13. The existing wetland can be utilized only in those options proposed in Site 1. The storage capacity presented in

Table 7-1 is the total capacity of all lagoons in the system including both the existing and proposed cells. Options 5 and 6 are proposed to provide a total storage capacity of 10 months, with provisions for expanding the new cells to provide additional storage capacity of 2 months, bringing the total capacity to 12 months. The major aspects in conceptual design are presented in the following sections.

Schematic design figures for the 6 lagoon options can be found in Appendix B.

Table 7-1: Schematic Design Options

Site	Option Number	Total System Storage (months)	Wetland Availability	Description
Site 1	Option 1	10	Yes	New cell addition to the east and the existing lagoon
	Option 2	10	Yes	New cell addition to the east and retrofitted existing lagoon
	Option 3	12	Yes	New cell addition to the east and new cell over demolished existing cell
	Option 4	12	Yes	New cell addition to the east
	Option 5	10 with provision for additional 2	Yes	new cell addition to the north and the existing lagoon
Site 13	Option 6	10 with provision for additional 2	No	new lagoon

For design of the options that includes utilization of the existing lagoon, the effective storage volume of the existing lagoon is considered 40,000 m^3 as opposed to its total volume of 43,000 m^3, which is equivalent to a storage capacity of three months. Table 7-2 presents the design values and characteristics of the proposed lagoons in the six options.

Table 7-2: Design Characteristic for the Proposed Lagoon Cells

Parameter	Value	Unit
Design population	4,338	person
Design storage duration	7-12 (variable; based on option)	month
Design berm slope	3:1 (H:V)	-
Design freeboard	1	m
Design effective water depth	1.7	m
Design sludge depth	0.3	m
Berm top width	3.0	m

7.2.1 Option 1 – New Cell and Existing Lagoon at Site 1

In this option, the sewage disposal facility will still be located in Site 1, similar to the existing facility. This option will provide a total effective storage capacity of 10 months (133,000 m^3). The existing lagoon will continue to operate, providing an effective storage capacity of 3 months (40,000 m^3). A new cell will be constructed east of the existing lagoon to provide an additional effective storage capacity of 7 months (93,000 m^3). Truck dumping will occur into the new cell, then effluent from the new cell will discharge into the existing cell through an overflow spillway before it discharges to the wetland. The layout of Option 1 is presented in the attached drawing C-101 and found in Appendix B.

The construction sequence of Option 1 is relatively simple. The new cell can be constructed while the existing cell is functional and receiving truck dumping. The overflow spillway connecting the existing cell with the new cell does not require the operation to pause.

Operation of the proposed lagoon system is described as following:

- A new dumping pad will be constructed at the east end of the new cell to accept the sewage truck dumps;
- The sewage will be retained in the new cell for 10 months for 3,000 people (2020) and for 7 months for 4,338 people (2040);
- At the end of retention time when the new cell is full, the water will overflow to the existing cell; and
- When the permeable portion of the berm is not frozen, the water in the existing cell will seep through the permeable berm section at a slow and continuous rate during the summer months. The water in the new cell can be released to the bottom level of the active water volume by either opening a plug valve or by pumping. The water level in the lagoon is consistently 2m below the top of berm.
- As it is difficult to assume any storage capacity within this cell, due to the permeability of the western berm, storage volume cannot be considered. This is a key component and leads to the rejection of this option.

7.2.2 Option 2 – New Cell and Retrofitted Lagoon at Site 1

Similar to Option 1, the sewage disposal facility will still be located in Site 1. This option will provide a total effective storage capacity of 10 months (133,000 m^3). The existing lagoon will continue to operate; however, it will be retrofitted by removing the permeable berm and replacing it with a containment berm. Impact of this retrofit on the storage capacity cannot be estimated at this point since the dimensions of the existing permeable berm are not available. Based on the satellite photo, it is estimated that the south berm is 160m in length. At least the south berm should be lined. A detailed investigation on the rest of the berms should be conducted to determine if the rest berm should be lined.

It is assumed the retrofitted cell to provide the same effective storage capacity of 3 months (40,000 m^3) as in Option 1. In addition, a new cell will be constructed east of the existing lagoon to provide an additional effective storage capacity of 7 months (93,000 m^3). Truck dumping will occur into the new cell, then effluent from the new cell will discharge into the existing cell through an overflow spillway before it discharges to the wetland. The layout of Option 1 is presented in the attached drawing C-102 and found in Appendix B.

The construction sequence of Option 2 is different from Option 1 due to retrofitting of the existing lagoon. The new cell will be construction while the existing lagoon is functional. After the new cell is commissioned, it will take over receiving truck dumping and the existing cell will be out of service for retrofitting. During that time, an interim pumping system will be used to discharge the new cell's effluent to the wetland. After the existing lagoon is retrofitted, it will be back to operation by connecting to the new cell through an overflow spillway and discharge to the wetland will be from the retrofitted lagoon.

Operation of the proposed lagoon system is similar to that described in Option 1 except that discharge from the existing lagoon to the wetland will be by overflow or pumping rather than seepage through a permeable berm.

7.2.3 Option 3 – Two New Cells at Site 1 Over Demolished Existing Cell

This option will provide a total effective storage capacity of 12 months (160,000 m^3) at Site 1. The existing lagoon will be demolished and be replaced with a new cell with an effective storage capacity of 2 months (27,000 m^3). In addition, another new cell will be constructed to the east to provide an effective storage capacity of 10 months (133,000 m^3).

Truck dumping will occur into the new cell, then effluent from the new cell to the wetland before it discharges to the wetland. The layout of Option 3 is presented in the attached drawing C-103 and found in Appendix B. The construction of this option is anticipated to have the same order of Option 2.

The existing cell has hold water in the last decade. It is expected that the groundwater might be high at this location. The undergrade layer might have been weakened due to the present of the groundwater. A detailed geotechnical study or test pit should be conducted to investigate the ground water conditions in the detailed design stage.

7.2.4 Option 4 – One New Cell at Site 1 Over Demolished Existing Cell

This option will provide a total effective storage capacity of 12 months (160,000 m^3) at Site 1. The existing lagoon will be demolished, and one new cell will be constructed at the same site, but on a larger footprint, to provide the total effective storage capacity. Truck dumping will occur into the new cell, then effluent from the new cell will discharge to the wetland. The layout of Option 3 is presented in the attached drawing C-104 and found in Appendix B.

During demolishing of the existing lagoon and construction of the new cell, sewage will be directly transferred to the wetland by pumping. Operation of the proposed lagoon system in this option is similar to that described in Option 2 except that Option 3 includes only one cell. Similar to Option 3, a groundwater and foundation study should be conducted in the detailed design stage to determine how the new berms can be constructed.

7.2.5 Option 5 – New Cell Addition to the North

Option 5 will provide a total effective storage capacity of 12 months (160,000 m^3). This option will have the similar design as in Option 1 except the following differences:

- The new cell will be added to the area north of the existing local road (Area B); and

- Overflow spillway is not feasible as the road is in between the two cells. The operator can use a pumping system to transfer the water from the new cell to the existing cell.

The Option 5 conceptual design layout is presented in C-105 and found in Appendix B.

In this option, a provision for increasing the storage capacity of the new lagoon will be assessed in the future based on future population and achieved water quality. This upgrade can be implemented by expanding the east side of the new cell, as presented in the drawing C-105.

The geotechnical study and site reconnaissance found that, compared to option 1, the land north to the existing local road has more wet pockets and is too close to the water body to the north. This makes the construction of the new cell more challenging and more expensive.

Furthermore, the interconnection pipe might be frozen in wintertime. The hamlet can use pump to divert the wastewater from the north new cell to the existing cell before it is frozen. This will add another layer of operation complexity.

7.2.6 Option 6 – New Lagoon in Site 13

This option involves a single lagoon cell with a total storage capacity of 10 months (133,000 m^3) in Site 13 in the design year 2040. The conceptual layout is presented in C-106 in the attached drawing set. As indicated in the drawing, the existing access road will need upgrades to allow truck haul to the Site 13. The new lagoon system will need a new outfall to allow the discharge to the ocean or a new wetland system. With these two additional components and a full-size cell, the construction of the Option 6 system is deemed more expensive than the other options.

Similar to Option 5, a provision for increasing the storage capacity of the new lagoon will be assessed in the future based on future population and achieved water quality. This upgrade can be implemented by expanding the west side of the new cell, as presented in the drawing C-106 and found in Appendix B.

It should be noted that the Hamlet is not in favor of moving the sewage disposal facility to a new location and it would have a negative impact on currently undeveloped land. It also has a high probability of changing bird flying patterns across the airport runway.

7.3 SCHEMATIC DESIGN

7.3.1 Lagoon Sizing

As discussed in Section 6.0, two sites (Site 1 and Site 13) have been identified as the preferred sites for the lagoon expansion. In Site 1, the existing lagoon cell can be kept in operation to work with a new cell. In Site 13, a new cell will be constructed as the only cell to receive all the truck dump water. Ideally, according to the CSA W203:19, the single cell lagoon should be sized to have 12 months storage volume for the design year to maximize the primary treatment. However, construction of the lagoon system with the full storage volume will require high capital spending, in addition to the land constraints around the existing lagoon. To overcome these two challenges, the lagoon can be designed to accommodate 10 months of storage rather than 12. The best-case scenario for this solution if the community grows at lower rates that expected in this study future, so the actual population is less than the projections. Having a wetland area downstream of the lagoon is anticipated to polish its effluent and provide an environment for further treatment, which compensates for the two-month difference in storage capacity. In all cases, the water quality at the compliance point should be monitored to ensure the effluent criteria are satisfied. Upgrades can still be considered in the future to accommodate the two-month difference if the actual population growth matches the projection. On the other hand, the lagoon with the winter storage capacity (10 months) can allow the wastewater to discharge multiple times to the wetland in the summer and fall seasons the wetland is most active.

Table 7-3 presents the required active storage volumes for 10- and 12-months storage.

Table 7-3: Required 10- and 12-Months Active Storage Volumes (Excluding Sludge Accumulation Allowance and Freeboard)

Year	Population	Total Required Active Storage Volume (m³)	
		10 months	12 months*
2020	3,006	91,382	109,719
2021	3,075	93,480	112,238
2022	3,143	95,547	114,720
2023	3,210	97,584	117,165
2024	3,275	99,560	119,538
2025	3,340	101,536	121,910
2026	3,405	103,512	124,283
2027	3,467	105,397	126,546
2028	3,528	107,251	128,772
2029	3,590	109,136	131,035
2030	3,652	111,021	133,298
2031	3,715	112,936	135,598
2032	3,780	114,912	137,970
2033	3,845	116,888	140,343
2034	3,912	118,925	142,788
2035	3,980	120,992	145,270
2036	4,049	123,090	147,789
2037	4,120	125,248	150,380
2038	4,191	127,406	152,972
2039	4,264	129,626	155,636
2040	4,338	131,875	158,337

Note: The active volume of the existing lagoon cell is estimated to be 40,000 m³.

* Based on the storage requirements by the CSA W203:19.

As indicated in the table, if the population grows as projected, the required 10-month storage volume in 2040 is equal to 12-month storage in 2029.

Table 7-4: Required 10- and 12-Months Active Storage Volumes (Excluding Sludge Accumulation Allowance and Freeboard) for the New Cell

Year	Population	Total Required Active Storage Volume for the New Cell (m^3)	
		10 months*	12 months**
2020	3,006	51,382	69,719
2021	3,075	53,480	72,238
2022	3,143	55,547	74,720
2023	3,210	57,584	77,165
2024	3,275	59,560	79,538
2025	3,340	61,536	81,910
2026	3,405	63,512	84,283
2027	3,467	65,397	86,546
2028	3,528	67,251	88,772
2029	3,590	69,136	91,035
2030	3,652	71,021	93,298
2031	3,715	72,936	95,598
2032	3,780	74,912	97,970
2033	3,845	76,888	100,343
2034	3,912	78,925	102,788
2035	3,980	80,992	105,270
2036	4,049	83,090	107,789
2037	4,120	85,248	110,380
2038	4,191	87,406	112,972
2039	4,264	89,626	115,636
2040	4,338	91,875	118,337

* For the option 1, 2, 5, and 6.

** For options 3 and 4, and expanded options 5 and 6.

7.3.2 Lagoon Design Considerations

7.3.2.1 Lagoon Seepage Control

The wastewater lagoons must retain wastewater for a specified amount of time for adequate treatment. The liners in the lagoon ponds are designed to prevent the wastewater from seeping from the lagoon cell berms and bottoms. Uncontrolled wastewater seepage to the environment may pollute the underground water and the surrounding environment, such that, a properly designed liner is critical to the lagoon systems.

The two (2) most common liners in northern Canada for wastewater lagoons are clay liners and synthetic liners (HDPE liners) for their low cost and ease of installation. The geotechnical study recommended that a synthetic liner for the seepage control in the proposed lagoon cells as suitable clay was not found. Accommodate for settlement and stretching of the liner in response to localized thawing will be considered in the detailed design.

Depending on the ground water level, an underdrain system might be needed to drain the groundwater and expel potential endogenous gases released from organics decomposition. This potential solution will prevent gases from accumulating under the HDPE liner forming large bubbles.

7.3.2.2 Groundwater Monitoring

At least four monitoring wells will be installed around the new lagoon cells. It is normally intended to use the geotechnical investigation bore holes and convert them to monitoring wells for groundwater monitoring. However, the geotechnical investigation bore holes are normally damaged during construction. The number of the monitoring wells and their location will be determined in the detailed design stage.

In the first year of operation, groundwater will be monitored with a groundwater monitoring program to evaluate the efficiency of the seepage control.

7.3.2.3 Operation Considerations

The operation of the Hamlet lagoon involves the receiving of the truck-in sewage dumping, discharge of the effluent and routine inspection and maintenance of the lagoon cells.

During sewage disposal into the lagoon, trucks will dump sewage collected from holding tanks of the houses or buildings within the Hamlet. As there are not external users that haul in sewage, there is no need to monitor the sewage dumping with a septic receiving station or other monitoring and metering system. A dumping pad will be designed and constructed to handle the traffic loads from the dumping activities. To prevent the liner damage from the dumping activities, e.g., some trucks might have metal end hose (Camlock fitting). The metal end might cause damage to the HDPE liner. A concrete pad (cable concrete mattress or its alternative) can be installed at the dumping location to protect the liner.

The treated effluent from a passive lagoon can be discharged with the following optional approaches:

1. The effluent is discharged through a plug valve in the discharge pipe at the bottom of the storage cell. The discharge speed can be controlled by throttling the valve. It is the simplest way in term of installation and operation. Compared to pumping option, it does not require energy input and operator’s attention. However, there is a possibility that the discharge pipe and valve might be frozen in the early discharge season, which will hinder the discharge.

2. The effluent is discharged through a high permeable berm portion. The existing lagoon discharge was constructed with the discharge berm. The discharge of the water is passive without rate control. When the permeable berm portion is unfrozen, water will seep through the berm. A certain degree of treatment occurs in the seeping process, e.g., the organic matter can be absorbed by the gravel and sand particles, the biofilm formed on the granules can degrade the organics.

3. The effluent is decanted with a pump. In the discharge season, a dewatering pump on a mobile skid can be installed in the berm. A suction hose will be deployed into the water in the cell and the discharge hose will be placed to the discharge point (wetland). The discharge rate is controlled by the pump speed. The pump will require fuel and energy and operator's attention to keep it in good operation condition.

7.3.2.4 Other Considerations

The embankment of the lagoon will be constructed according to the recommendations from the Geotechnical Report. For example, the berms should have a minimum slope of 3:1 (H:V). Ideally, the earth movement should be balanced within the construction limit to avoid borrow or export the material to keep the construction cost low. However, the geotechnical study recommends that the lagoon should be constructed on the 0.5 m backfill layer on the existing grade.

Fence, turf establishment, and possible interconnection structures, e.g., overflow spill way between the existing and the new cell in Option 1, will be designed during detailed design. For access control and public safety, barbed wire fences around the lagoon sites could be installed should the Hamlet deem necessary.

7.3.3 Sludge Management

The biosolids or sludge residual settled at the bottom of the lagoon cells are the results from the biological and physical treatment of the wastewater organic matter and inorganic matter. The accumulated sludge volume will occupy the cell volume if it is not removed in time. The sludge generation rate of 0.35 L/person/day as in the CSA W203.19 can be used to estimate the sludge volume. For the conceptual design, the sludge volumes are presented in the following Table 7-5. With a water area of 9 ha, the average sludge depth based on the 20-year sludge volume based the CSA standard will be 0.1m. In current conceptual design, a sludge depth allowance of 0.3 m is recommended.

In the operation, when the lagoon effluent is pumped out or released each year, the operator should control the water depth so that the sludge will not be released. The turbidity or the TSS parameters can be used to monitor if sludge has been released. The operator can also use a contractor to conduct a sludge survey to determine the actual sludge depth and when to remove the sludge. The sludge survey can be carried out once every 5 years or if the turbidity or the TSS readings are high. If the accumulated sludge is found to be at 0.15 m depth, the sludge can be removed.

The sludge from the proposed lagoon cells can be removed by dredging. The dredged sludge can be temporarily stored in filter bags (for example Geotube) to dewater to reach 20% solid. With the reduced volume, the dried sludge can be hauled to and land fill for final disposal.

Table 7-5: Required Sludge Storage Volumes

Year	Population	Sludge Volume (m^3)	Accumulated Volume (m^3)
2020	3006	384	384
2021	3075	393	777
2022	3143	401	1178
2023	3210	410	1588
2024	3275	418	2007
2025	3340	427	2434
2026	3405	435	2869
2027	3467	443	3311
2028	3528	451	3762
2029	3590	459	4221
2030	3652	467	4687
2031	3715	475	5162
2032	3780	483	5645
2033	3845	491	6136
2034	3912	500	6636
2035	3980	508	7144
2036	4049	517	7662
2037	4120	526	8188
2038	4191	535	8723
2039	4264	545	9268
2040	4338	554	9822

Sample calculations:
Sludge volume of 2040 = 4,338 × 0.35 × 365 ÷ 1,000 = 554 m^3
Accumulated sludge volume at 2040 = 554 + 9,268 = 9,822 m^3

7.3.4 Freeboard

"Freeboard" is the minimum vertical distance between water line inside the lagoon and its berms. The Arviat water licence recommends a minimum freeboard of 1.0 m for the sewage disposal facility, which was originally recommended by the CSA W203.19. However, the licence allows using other limits as recommended by a qualified professional engineer and as approved by the AWB. The value of the freeboard will impact the storage capacity of the existing lagoon or the footprint of the proposed lagoon cells due to the sloped sides of the lagoons. In other words, using a smaller freeboard for the existing lagoon will result in further utilization of its volume and additional storage capacity. On the other hand, for the new cells, using a smaller limit for the lagoon's freeboard will result in a smaller footprint.

Since there are land restrictions on expansion of the current sewage disposal facility, it is worth studying the feasibility of reducing the lagoon's freeboard limit to less than 1.0 to maximize the utilization of the available land in an alternate study. The Arviat water licence and the CSA W203.19 do not provide a further guidance on reducing the freeboard's lower limit. The US-EPA's textbook "Principles of Design and Operations of Wastewater Treatment Pond Systems for Plant Operators, Engineers, and Managers" reports that a minimum and maximum recommended freeboard varies from 0.6-0.9 m. Some states allow a 0.3 m freeboard for small systems, while others specify 0.6 m. However, systems with a smaller freeboard should have considerably constant water surface with no significant fluctuations due to operational (e.g., loading) or environmental (e.g., wind) factors. It also recommended to install riprap at the top of the slopes so it can damp fluctuations in the water surface.

At this conceptual stage, we have used 1 m freeboard in the lagoon layout design. The freeboard depth can be further reviewed in the next stage of design.

7.3.5 Other Considerations

Climate of the selected site should be considered in the design of the lagoon systems as it can impact their loading by environmental processes such precipitation or evaporation. Severe precipitation events (directly into the lagoon or from the upstream catchment area) can significantly contribute water to and affect the lagoon capacity. This must be considered in the design capacity of the lagoon when applicable. As described in Section 6.1.3.4, the total annual precipitation of Arviat is 286 mm, of which 112 mm (39%) fell as snow (Canadian climate normals, 1981–2010[10]). On the other hand, evaporation (or evapotranspiration) has the opposite impact on the lagoon's loading, which is highest during the summer months when solar radiation and heat are the highest.

The CSA W203.19 recommends that conservative values of annual precipitation and evaporation should be used in the storage calculations. The following is an example of conservative annual precipitation and evaporation historical data that can be used in the next stage of design based on the available information:

- Precipitation: a 20-year return period maximum precipitation
- Evaporation: a 20-year return minimum evaporation

During operation, snow accumulation at the lagoon' truck pad will be maintained by clearing the snow periodically. Clearing will occur each time the access to the road is cleared. Snow can be piled on both sides of the access road and truck pad in a way that does not obstruct the dumping activities.

7.3.6 Effluent Treatment Projections

7.3.6.1 Lagoon

The lagoons proposed in this conceptual design are equivalent to the single cell configuration defined in the CSA W203.19. Based on the studies conducted in Nunavut, single cell lagoons can reach a primary level of treatment, in which a significant level reduction of BOD and TSS is not expected. With an effective

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[10] https://climate.weather.gc.ca/climate_normals/

volume for 12 months' storage and effective water depth of less than 2.5 m, the expected effluent quality released at the end of the summer is:

- cBOD: 80-120 mg/L
- TSS: 50-100 mg/L
- TAN: 10 – 25% reduction
- Total phosphorus (TP): 30-50 % reduction
- *E.coli*: 10^5-10^6 CFU/100 mL

If the effective volume is designed for 10 months only, which is enough for the wintertime storage, it is expected that there is no significant biological treatment occurring during the storage period in the design year. The lack of biological treatment is due to the ice cover that limits natural aeration. The ice and snow cover also block sunlight so that the vegetation in the water can not grow and treat the water. In the summertime, the 10-month stored wastewater will be released without the same level of treatment as in a 12-month storage cell. Meanwhile, additional raw sewage will be dumped into the lagoon cell, which will further bring the effluent parameter values higher. There is no mathematical model that can project the effluent treatment results accurately, however, the treatment results are expected to have cBOD and TSS of less than 120 and 100 mg/L, respectively.

Note that as per Table 7-3, the design volume for 10 months storage in 2040 is slightly more than the required volume for the 12 months storage in 2029 if the population growth is aligned with the projections. It is expected that the effluent quality will be compliant with the proposed cBOD <120 mg/L and TSS <100 mg/L values until 2029 as presented in Table 2-3 due to the additional two months of treatment. Note that since TAN and TP removal is not significant in the single lagoon cell, the algae growth will be at high level in the proposed lagoon with 1.7 meter of effective water depth. The algae might increase the TSS level.

The TAN level will be expected to be as high as 100 mg/L in the effluent from the lagoon system with a 12-month retention time in 2040. Depending on the pH level at the time of discharge, which is also impacted by the algae growth, the unionized ammonia level can reach 8-10 mg/L if the pH is at 8.5. The TAN level from the lagoon with 10-month retention time is expected to be higher.

Note that the existing lagoon permeable berm might show performance similar to a filtration process, in which the cBOD and TSS or even TAN can be removed.

7.3.6.2 Wetland

In 2012, Yates *et al*. published a study paper on the Arviat wetland treatment results. The samples were taken from the end of the wetland and tested. The sample program occurred in 2010 when the Arviat population was 2,318 and the daily flow to the lagoon was 235 m^3/day. The test results are presented in Table 7-6.

Table 7-6 Arviat Lagoon Wetland Effluent Quality (Yates et al., 2012)

Parameter	Unit	Mean	Standard Deviation	Max	Min
cBOD	mg/L	16	6	24	6
TSS	mg/L	19.1	22.8	74	0
TAN	mg/L	11	10	40.4	0.4
E.coli	CFU/100 mL	898	1,350	4,510	4

Note: only parameters of interest are presented in the table, readers can refer to Yates et al. (2012) for the full results.

As indicated in the above table, the mean values of cBOD and TSS in the wetland effluent are close to a secondary treatment process effluent. The TAN is high at 11 mg/L. The high standard deviation values are high, which imply that as a natural treatment process, the wetland performance efficiency fluctuates.

According to CSA W203:19, the wetland should receive the lagoon effluent during the middle of the summer and/or the end of the treatment season. The Hydraulic Loading Rate (HLR – m^3/ha-d) is a parameter to determine the per unit area flow that the wetland can accept to provide a reasonable treatment efficiency. The Hydraulic loading rate (HLR) can be calculated with the following:

HLR = Qin ÷ Aw

Where Qin is the effluent discharged from lagoon into the wetland (m^3/d), and Aw is the wetted area of the wetland observed in active flow (ha).

The CSA W203:19 specifies a maximum HLR of 250 m^2/ha-d for lagoon effluent into the wetland. For a lagoon effluent flow rate of 434 m^3/d (as estimated in Section 4.1.2) and the wetland of 7.3 ha, assuming a three-month (90 days) discharge schedule, the required wetland area is 7 ha in the design year as per the following calculation:

Aw = 434 × (365 ÷ 90) ÷ 250 = 7.0 ha

Another parameter, Organic Loading Rate (OLR in kg cBOD/ha-d), can be used to determine the required area of a wetland. The CSA W203:19 stipulates that the OLR shall be a maximum of 8 kg/ha-day. The OLR can be calculated by:

OLR = BOD × Qin ÷ Aw

Where BOD is the cBOD in the lagoon effluent discharged into the wetland. From a 12-month single cell lagoon, the cBOD is expected to be at 80-120 or higher. Using a 120 mg/L and a 3-month discharge window, the required wetland area is 26.4 ha, which is three times the current wetland area, as per the following calculation:

Aw = (120 ÷ 1,000) × 434 × (365 ÷ 90) ÷ 8 = 26.4 ha

The CSA W203:19 also recommends a minimum of 14 days nominal Hydraulic Retention Times (HRT). The HRT may be calculated as following:

HRT = Aw × H ÷ Qin

Where H is the average depth of water in the wetland. It is assumed the water depth in the wetland downstream of the Arviat is 0.4 m. To achieve an HRT of 14 days, the required wetland area is 6.2 ha as per the following calculation:

Aw = 434 × (365 ÷ 90) ÷ 0.4 × 14 ÷ 10,000 = 6.2 ha

The three required wetland area calculation results based on the HLR, OLR and HRT indicate that the current wetland area of 7.3 ha might not be sufficient for the post lagoon treatment in design year 2040. However, further detailed study on the wetland is necessary to verify its actual treatment capacity based on field measurements and evaluate potential engineered improvements.

The sampling location was not pinpointed in the Yates *et al.* (2012) paper, however, it is assumed that the samples were taken from the end of the wetland treatment area to present the final water quality. Currently, the monitoring station ARV-4 is located close to the north end of the wetland, which closer to the inlet to the wetland than the discharge point to the ocean. As the current location does not reflect the complete treatment processes along the treatment path, it is suggested that ARV-4 should be relocated to the south end of the wetland treatment area to reflect the final water quality prior do discharge into the ocean.

7.4 CLASS D COST ESTIMATE

Despite the treatment benefit of the existing lagoon permeate berm can contribute to the overall treatment process, Option 1 design is not a preferred option as the retention time is affected by the real permeability of the berm. It is most likely that once the permeate berm cannot hold the water once it is thaw, the proposed 10 months retention time cannot be met. The Hamlet wanted to discard the Option 6 in Site 13 due to its long-distance hauling requirement. The following evaluation and selection processes hence excluded Option 1 and Option 6 design.

Table 7-7 shows Class D Cost Estimates for Options 2 to 5 which were prepared by Altus Group Limited, a Professional Quantity Surveyor (PQS). A detailed cost analysis is presented in **Appendix L**.

Table 7-7: Cost Estimate for the Schematic Design Options

Option		Total Construction Cost Estimate ($Million)
	[redacted]	
	[redacted]	
	[redacted]	
	[redacted]	

7.5 EVALUATION OF SCHEMATIC DESIGN OPTIONS

The following weighting was assigned for each category based on specific requirements for this application. There are five criteria to be used in the matrix, each is given a score with a total score of 100. The highest the score, the more favourable the option is. Table 7-8 lists the criteria and weighing.

Table 7-8: Evaluation Criteria of the Schematic Design options

Criteria	Definition	Score
Treatment Performance	Effectiveness of the treatment system in providing a high-quality effluent; based on the retention time in lagoons and availability of a wetland.	30
O&M Requirements	Easiness of O&M to the operation personnel.	20
Site Ranking	Convenience of the site to the overall waste management system (based on the site selection matrix).	15
Capital Costs	Capital cost estimate.	15
Operation and Maintenance (O&M) Costs	Annual O&M cost estimates.	10
Hamlet's Preference	The Hamlet preferring specific options over others.	10

Table 7-9 shows the scoring of the six schematic design options.

Table 7-9: Scoring of the Schematic Design Options

Site	Option	Scoring Treatment Performance	O&M Requirements	Site Ranking	Capital Costs	O&M Cost	Hamlet's Preference	Total Score
Criteria Score		30	20	15	15	10	10	100
Site 1	Option 2	20	20	15	14	9	5	**83**
	Option 3	30	20	15	9	8	10	**92**
	Option 4	25	20	15	10	10	5	**85**
	Option 5	20	10	12	15	5	5	**67**

7.6 RECOMMENDATION

Based on evaluation of the four schematic design options presented in Table 7-9, Stantec recommends Option 3 to be implemented at the same site of the existing lagoon (Site 1). In Option 3, the existing lagoon will be demolished and be replaced with a new cell with an effective storage capacity of 5 months (67,000 m^3). A new cell will be constructed to the east to provide an additional effective storage capacity of 7 months (95,000 m^3), bringing the total effective storage capacity up to 12 months (162,000 m^3).

Option 3 had the highest ranking in Treatment Performance due to having the highest HRT of 12 months as well as due to being composed of two lagoon cells, which improves the treatment kinetics as opposed to single-cell lagoons. The two-cell configuration has more flexibility in operation; with one cell is taken off-line, the other one can stay in operation.

Lower rankings were given to the other options for having a shorter HRT or being composed of a single cell. All options were given similar ranking for the O&M Technical Requirements except for Option 5, which was given a lower ranking for involving a pumping component. Similarly, all options had the same ranking for the Site Ranking except for Option 5 due to the location of the proposed second lagoon across the road. Ranking for the Capital Costs were based on the estimated costs, while ranking for the O&M Costs were based on whether there is a mechanical component as well as on the size of the lagoons. Finally, the Hamlet's Preference was toward Option 3, giving this option higher ranking than the others.

Note: The quantities estimated for construction of Option 3 are included within the Class D Cost Estimate in Appendix L. These quantities are summarized below:

- Occupied Area 135,000 m^2

  Area needed to construct the cells; add 10 meters from the berm top to edge

- Total Fill Volume 83,150 m^3

  Total fill material needed to construct the berms

- Total Cut Volume 67,400 m^3

  Total cut material to level the bottom (if any)

- Total Internal Surface 135,900 m^2

  Total internal surface, from berm internal edge to the cell bottom, plus the bottom. Can be used to calculate the fine grading, HDPE liners (60mil)

- Perimeter 953 m

  Fence length

8 CONCLUSIONS AND RECOMMENDATIONS

Stantec recommends Option 3 to be implemented at the same site of the existing lagoon (Site 1) based on evaluation of the six schematic design options presented in this Business Case. In this option, the existing lagoon will be demolished and be replaced with a new cell with an effective storage capacity of 5 months (67,000 m^3). A new cell will be constructed to the east to provide an additional effective storage capacity of 7 months (95,000 m^3), bringing the total effective storage capacity up to 12 months (162,000 m^3).

In order to complete the design of the recommended option, the following technical studies are to be completed:

- Wetland Study: the wetland study will confirm the capacity of the post lagoon wetland treatment capacity to determine if a wetland expansion is needed.
- Detailed Geotechnical Study for Lagoon Design: a detailed geotechnical study is needed in the detailed design stage to supply geotechnical data for the foundation, liner, and berm design.
    - The Geotechnical Study completed as part of this business case covers serval sites. It was an initial drilling program for site selection purpose. On Site 1, the required cell sizes and layouts have been determined. As part of consideration to the preferred Option 3, we are recommending an additional detailed Geotechnical Study be completed as part of the detailed design scope of work. This will include additional boreholes around the proposed Option 3 and consider groundwater, surface drainage, bedrock, and soil conditions. Further details pertaining to this supplementary Geotechnical Study can be found in "Design and Construction of Liners for Municipal Wastewater Stabilization Ponds in Alberta".
    - The existing lagoon should be investigated as part of this study and include testing the permeability of the existing berms to make sure the west, north, and east berms still hold water, as well as the permeability rate of the south berm. Commentary should be provided on the stability of these berms.
- Detailed Survey and Assessment of the Existing Lagoon: a study on the existing lagoon cells should be conducted to study the permeability of the existing berms and cell bottom. The study will confirm if the existing berms and bottom should be retrofit or removed in new cell construction. This can be carried out along with the detailed geotechnical study.

Appendices